MARCH 1971
CONTRACT F 61052-68-C-0060

FINAL TECHNICAL REPORT

NORSAR PHASE 2

INSTALLATIONS 1969 AND 1970

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NORWEGIAN DEFENCE RESEARCH ESTABLISHMENT
P O Box 25 - N-2007 Kjeller - Norway

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INTERN RAPPORT S-51

This research project has been sponsored under the technical direction of the HQ ELECTRONIC SYSTEMS DIVISION (AFSC) through the European Office of Aerospace Research, OAR, United States Air Force, and is under the over all direction of the Advanced Research Projects Agency.

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Project Leader	: Ø Brandtzæg, Major, NDRE to 31 July 1970
	A Lillegraven, Res Eng, NDRE since 31 July 1970
Title of Contract	: "Norwegian Seismic System, Phase 2"

FOREWORD

This research project is sponsored and supported by the Advanced Research Projects Agency of the Department of Defense. Technical guidance and direction for Contract No F61052-68-C-0060 has been provided by the Electronic Systems Division (AFSC). Contract support was provided by the European Office of Aerospace Research (EOAR), the R&D Contracts Division of ESD and the Air Force Logistics Command (Contract Management Center Det 16). This report covers the period from May 1969 through December 1970.

We wish to acknowledge the very considerable support and assistance provided during the course of this project by the Nuclear Test Detection Office (ARPA), the Seismic Array Program Office (ESD), the European Office of Aerospace Research (EOAR), the Seismic Array Analysis Center (SAAC) of IBM, and Teledyne, Geotech Division.

This report has been reviewed and is approved.

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CONTENTS

NORSAR PHASE 2 - INSTALLATIONS 1969 AND 1970

ABSTRACT

Phase 2 of project NORSAR (Norwegian Seismic Array) covers planning and construction of 21 out of the 22 subarrays constituting the large seismic array, standardization of the Øyer subarray built in Phase 1, installation of a Data Processing Center (DPC) at Kjeller, establishing of a telecommunication system connecting the DPC to all subarrays with 24 hours a day/2400baud channels, and establishing of a maintenance group with technical facilities.

Interim Technical Report, NORSAR Phase 2, The 1968 Installation Program, dated November 1969, describes installation of the central 8 subarrays. The present Final Technical Report covers the remainder of the installations, implemented during the period spring 1969 to December 1970.

1 INTRODUCTION

1.1 Report coverage

Earlier stages of the installations under the NORSAR project (governed by contracts F61052-68-C-0009 and F61052-68-C-0060 between the Electronic Systems Division (ESD) of the USAF and the Norwegian Defence Research Establishment (NDRE)) have been covered by the following main technical reports:

(1) Final Technical Report, NORSAR Phase 1

(2) Interim Technical Report, NORSAR Phase 2
The 1968 Installation Program

The present report describes installation of the remainder of the large array, i e subarrays 02C through 14C belonging to the outer C-ring.

Since (2) in certain respects goes beyond the calendar year 1968, it is not possible to define its exact time limits. Roughly the time period covered by the present report starts spring/early summer 1969 and expires by the end of 1970.

1.2 Other documentation

Considering the amount of hardware installed in the field in 1969 and 1970, some 60% of the total effort, the present report text has been kept rather concise compared with (1) and (2). This has been made possible by extensive use of references to (2) and to other technical documents produced under contract F61052-68-C-0060.

Designs, methods and procedures used in the 1969 and 1970 field installations are to a large extent dealt with in (2) and also in (1), and detailed descriptions of such have therefore been confined to innovations and modifications.

Comprehensive information, including quantitative data concerning most aspects of the array, has been collected in a series of documents listed below. They are referred to as DOC I through DOC V.

Document No	Contents
I	- coordinate lists for all SP and LP vaults in the array - descriptions of access route to all SP and LP sites - map 1:50 000 for each subarray, showing cable routes and seismic points - site plans for all CTV/LPV station areas - drilling reports for all SP holes (short and long) in the array
II, parts 1, 2 and 3	For each subarray: - a sketch of the air photo coverage of the cable trench network including the seismic points - a list of landowners affected by trenches or vaults, each landowner identified by a number - air photos in scale 1:5000 on which are traced and marked all site trenches, land boundaries and landowners by identification number
III	- diagrams of all electrical and electronic subarray circuits in front of the Short and Long period Electronic Module (SLEM) - drawings of layout and mechanical details of the electrical installations
IV, parts 1 and 2	- methods and procedures used in the check-out of SP and LP seismometers and of associated equipment in the CTV (Part 1) - a complete set of the data sheets produced during the check-out of seismometers.
V	- constructional drawings of short and long holes for SP seismometers, Well Head Vault (WHV), Long Period Vault (LPV) and Central Terminal Vault (CTV)

Table 1.1 Documentation of array field installations

Most of the documents listed in Table 1.1 are too detailed to be of general interest, and no external distribution has been implemented. Anyone wishing to have information contained in these documents should contact Project NORSAR, Box 51, N-2007 Kjeller, Norway.

Examples of the data presentations included in the present report are as follows:

DOC I	- coordinate list	Table 2.1
"	- description of access route	Figure 2.15
"	- drilling report	Figure 3.17
DOC II	- air photo coverage, subarray 10C	Figure 4.1
"	- landowner list, subarray 10C	Figure 4.2
"	- air photo, sheet E4, subarray 10C	Figure 4.3
DOC IV	- data sheets, SP and LP seismometer check-out	Figures 7.1 through 7.8

2 SITING AND LAND ACQUISITION

2.1 Extent of the siting effort

In its final configuration NORSAR consists of 22 subarrays, each of them based on 6 seismic monitoring points (see (2), p 13), i e altogether 132 locations. Of these, 9 subarrays with 54 separate locations had been sited and constructionally prepared by the end of 1968. (These numbers include the Øyer (01C) subarray, and take into account the later reduction in its number of seismic points, from 12 to the standard 6.)

It was realized already in summer 1968 that even if the overall building program of 21 new subarrays could be shared on a ratio of 8:13 between building seasons 1968 and 1969, a much larger portion of the siting effort had to be done in 1968. Thus, to enable the earliest possible starting dates for the 1969 subarray construction, another six subarrays were sited during fall 1968. Three of them (04C, 07C, 08C) were low altitude ones, picked as being suitable for an early start on construction, while the others (02C, 03C, 10C) represented high altitude areas where late snow melting might seriously delay detailed siting.

By the turn of the year, 7 subarrays remained to be sited, viz 05C, 06C, 09C, 11C, 12C, 13C and 14C.

2.2 Changes in the siting requirements

Special SP noise studies performed in 1967 under Phase 1 as well as in 1968 (see (2), p 87) had shown that the increase in the signal/noise ratio with seismometer depth in the rock was moderate, and did not warrant the extra cost involved in drilling deep holes.

A couple of changes in the siting requirements were introduced as a result of this:

a) The 60 m deep hole, drilled adjacent to the LPV in all A- and B-subarrays, should be omitted in the C-ring.

b) Given a certain computer-picked area for location of an SP point, the preference for a surface (rock outcrop) hole as compared with a deep hole drilled through overburden - maintained also for the 1968 sites - should be given even more emphasis.

2.3 Detailed siting

The various steps preceding the final staking of the seismic points in the field were largely identical to those used in 1968. The IBM optimum centroid configuration in force was a result of a revision made necessary by relocations during siting of the six 1969 program subarrays sited fall 1968. This array pattern proved to be the final one, the deterioration in array properties introduced by staking of the seven remaining subarrays was insignificant.

Preliminary siting started already in the middle of January 1969. Since the ground was snow-covered, siting had to be based on studies of air photographs and advice from local landowners, forest intendants, etc. In April and May, when snow started

to disappear in most subarray areas the effort was intensified, e g by using helicopter transport from site to site.

As more detailed information about the proposed sites was collected, a large number of them had to be relocated. The reasons varied:

a) At places where a deep hole could not be avoided, test drilling revealed excessive depth of loose deposits over the bedrock.

b) The access to the site proved too difficult.

c) The location was too close to a source of seismic noise (brook, timber road).

d) The landowner of the proposed site was reluctant to accept the installation on his ground.

The siting of the CTV/LPV and SP sites was completed by the end of June 1969. An overall map of the array is shown in Figure 2.1. Table 2.1 gives the final coordinates of the seismic points in the C-ring subarrays. Maps of the subarrays are presented in Figures 2.2 through 2.14. Because of map inaccuracies the coordinate list may disagree with map plotted points. Coordinate list is correct in all cases. Figure 2.15 shows an example of an access description for a seismic point within a subarray.

Site	Cartesian °North	°East	UTM system zone 32 x	y	Altitude in meters above sea level
01CLP	61°20'14.8863"	10°35' 7.5135"	680 1569.030	584 836.008	978.43
01COY	61°20'13.4546"	10°35' 8.2385"	680 1524.999	584 847.858	974.54
01CA1	61°21'17.2450"	10°32'36.2904"	680 3444.364	582 542.923	922.22
01CA2	61°22'59.9818"	10°28'25.5383"	680 6536.715	578 746.490	904.95
01CA3	61°24'13.9596"	10°31'50.6081"	680 8895.390	581 736.124	1004.63
01CC1	61°20'46.2759"	10°38' 4.0405"	680 2604.810	587 435.264	918.80
01CC2	61°21'12.9977"	10°43' 4.9589"	680 3546.275	591 884.295	961.67
01CC3	61°19'29.9726"	10°42'49.3073"	680 0353.020	591 735.483	799.45
01CD1	61°18'32.0614"	10°38' 0.6381"	679 8451.451	587 488.536	931.81
01CD2	61°17'38.2190"	10°42'20.3333"	679 6884.583	591 395.026	864.40
01CD3	61°16' 9.3848"	10°37'45.4451"	679 4031.946	587 372.649	990.42
01CF1	61°18' 0.8621"	10°31' 5.7732"	679 9913.060	581 279.788	989.98
01CF4	61°20' 2.2700"	10°34'17.3629"	680 1160.699	584 100.071	928.35
02C00	61°16'50,4921"	10°50' 7.4132"	679 5596.642	598 387.477	847.07
02C01	61°17'55.7048"	10°54'49.8716"	679 7734.602	602 533.470	1033.10
02C02	61°15'16.2379"	10°54'39.4914"	679 2797.208	602 523.358	1054.13
02C03	61°14'37.8121"	10°49'54.5548"	679 1486.914	598 311.143	714.60
02C04	61°16'33.3783"	10°45'46.4103"	679 4960.186	594 515.985	851.15
02C05	61°19'23.1899"	10°49'21.9076"	680 0301.290	597 578.143	958.57
03C00	61°15'42.1596"	11°24'50.9030"	679 4492.413	629 481.051	366.03
03C01	61°16'34.3000"	11°29'25.7390"	679 6258.670	633 512.816	290.15
03C02	61°13'57.9289"	11°28'21.3822"	679 1386.142	632 737.869	300.78
03C03	61°13'30.4434"	11°22' 8.5651"	679 0330.096	627 210.966	401.50
03C04	61°16'42.4397"	11°19'55.2705"	679 6196.816	625 011.334	393.93
03C05	61°17'52.5649"	11°24'12.5273"	679 8504.526	628 761.033	312.08
04C00	61° 4'44.6726"	11°43' 7.9837"	677 4802.674	646 665.505	522.40
04C01	61° 4'49.3993"	11°47'57.9080"	677 5132.014	651 001.730	583.31
04C02	61° 2'40.5527"	11°45'26.3601"	677 1051.308	648 899.894	450.56
04C03	61° 3'13.4686"	11°40' 5.9093"	677 1869.980	644 053.355	304.80
04C04	61° 5'53.4464"	11°38'44.2690"	677 6767.481	642 629.430	332.55
04C05	61° 6'46.0384"	11°42'55.2134"	677 8547.774	646 318.405	496.15

Site	Cartesian °North	Cartesian °East	UTM system zone 32 x	UTM system zone 32 y	Altitude in meters above sea level
05C00	60°56'48.5460"	11°48' 1.3805"	676 0265.315	651 689.943	425.65
05C01	60°58'37.9490"	11°50' 3.6251"	676 3727.293	653 382.083	525.32
05C02	60°56'44.9758"	11°53' 3.6147"	676 0352.208	656 240.384	467.86
05C03	60°54'27.0983"	11°47'53.3527"	675 5886.353	651 756.042	350.92
05C04	60°57' 2.8275"	11°43'33.4130"	676 0536.894	647 641.207	391.06
05C05	60°58'53.6814"	11°46' 5.1025"	676 4060.430	649 777.511	354.08
06C00	60°44'50.3720"	11°27'30.2163"	673 7311.772	634 004.365	321.22
06C01	60°46'28.3955"	11°32'29.7973"	674 0515.832	638 421.489	248.66
06C02	60°44' 6.9543"	11°32'28.9724"	673 6141.357	638 578.406	305.57
06C03	60°42'18.0246"	11°28'50.5735"	673 2646.183	635 398.735	340.94
06C04	60°43'34.6953"	11°23'44.1020"	673 4844.818	630 667.158	378.05
06C05	60°46'37.3604"	11°24'37.2599"	674 0523.396	631 264.852	242.30
07C00	60°27'19.1931"	11°29'55.6830"	670 4887.858	637 442.132	221.50
07C01	60°29'38.1724"	11°30'49.4557"	670 9216.890	638 099.263	268.21
07C02	60°26'30.8225"	11°34'19.5752"	670 3547.369	641 531.136	224.19
07C03	60°24'49.9261"	11°31'44.3652"	670 0335.418	639 279.429	191.50
07C04	60°25'14.1342"	11°26'57.2186"	670 0918.031	634 860.180	207.57
07C05	60°28'33.0704"	11°25'37.9034"	670 7025.157	633 420.572	245.14
08C00	60°28'32.1622"	11° 5'12.4418"	670 6355.512	614 714.278	480.92
08C01	60°30' 7.9168"	11° 9'24.5494"	670 9441.071	618 465.955	236.59
08C02	60°26'45.9714"	11° 8'49.4279"	670 3177.806	618 133.975	458.02
08C03	60°27' 1.2571"	11° 1'43.2167"	670 3444.044	611 606.777	309.42
08C04	60°29'45.8574"	11° 0'49.6150"	670 8509.856	610 632.059	441.84
08C05	60°30'43.6307"	11° 5'13.8884"	671 0422.344	614 607.394	582.84
09C00	60°24'33.8159"	10°36'13.6448"	669 8238.598	588 346.677	478.76
09C01	60°27'16.6760"	10°38'23.0232"	670 3324.978	590 200.686	684.11
09C02	60°24'30.2621"	10°41'14.0780"	669 8243.495	592 945.973	665.82
09C03	60°22'32.9233"	10°39'17.4360"	669 4568.694	591 252.533	571.04
09C04	60°23'48.5139"	10°31'27.1462"	669 6733.193	583 995.722	339.99
09C05	60°26'22.8824"	10°33'32.0856"	670 1553.005	585 795.008	447.97
10C00	60°28'10.3196"	10°17'59.8294"	670 4567.246	571 478.867	403.86
10C01	60°29' 1.1374"	10°22' 6.7829"	670 6215.704	575 217.751	529.72
10C02	60°26'37.8152"	10°22' 8.5435"	670 1782.669	575 336.815	445.08
10C03	60°25'59.6738"	10°16'43.1658"	670 0502.792	570 386.498	425.01
10C04	60°27'53.2194"	10°14' 8.7904"	670 3970.297	567 960.237	392.71
10C05	60°30'35.4288"	10°16'36.5280"	670 9031.328	570 119.575	290.86
11C00	60°37' 1.6427"	10°14'59.0637"	672 0950.571	568 405.891	242.27
11C01	60°38'13.7137"	10°18'45.4501"	672 3247.201	571 803.152	401.48
11C02	60°34'20.4088"	10°15'25.8483"	671 5970.445	568 908.462	512.04
11C03	60°35'28.1325"	10°11'44.0547"	671 8002.588	565 493.710	429.56
11C04	60°37'57.7222"	10°11'10.6326"	672 2621.124	564 901,675	327.75
11C05	60°39'13.4876"	10°14'47.4537"	672 5025.976	568 152.034	534.52
12C00	60°46'22.4231"	9°59' 4.2799"	673 8053.174	553 629.757	637.28
12C01	60°48' 3.0767"	10° 2'19.0137"	674 1212.580	556 526.905	580.42
12C02	60°45'28.4900"	10° 3' 3.0905"	673 6440.622	557 269.789	676.38
12C03	60°43'53.2630"	10° 0' 3.4746"	673 3452.020	554 595.755	713.33
12C04	60°45'43.5013"	9°54'25.2584"	673 6788.175	549 424.612	763.03
12C05	60°48'38.0582"	9°56'56.0479"	674 2220.922	551 628.862	705.98
13C00	61° 2'59.4719"	9°53'10.0375"	676 8824.634	547 852.883	919.94
13C01	61° 5'40.2799"	9°53'42.4188"	677 3806.613	548 270.570	892.35
13C02	61° 4'14.6484"	9°57'33.6994"	677 1206.293	551 773.730	803.55
13C03	61° 1'41.0480"	9°56'17.3107"	676 6437.376	550 696.753	735.15
13C04	61° 1' 2.2735"	9°50'57.4154"	676 5172.168	545 910.563	697.19
13C05	61° 2'48.7745"	9°48' 3.6675"	676 8434.443	543 261.328	976.68
14C00	61°11'12.9241"	10°16'22.5956"	678 4435.463	568 443.683	492.75
14C01	61°13'29.6828"	10°21'17.2226"	678 8754.901	572 755.990	725.64
14C02	61°11'28.9249"	10°22'40.8044"	678 5044.997	574 081.454	563.12
14C03	61° 9' 9.9057"	10°18'32.5541"	678 0667.847	570 460.700	510.44
14C04	61° 9'50.7254"	10°12'52.4248"	678 1832.644	565 352.158	829.40
14C05	61°12'13.3368"	10°12'51.3663"	678 6244.551	565 254.396	507.69

Table 2.1 Coordinates of the seismic points in the C-ring subarrays

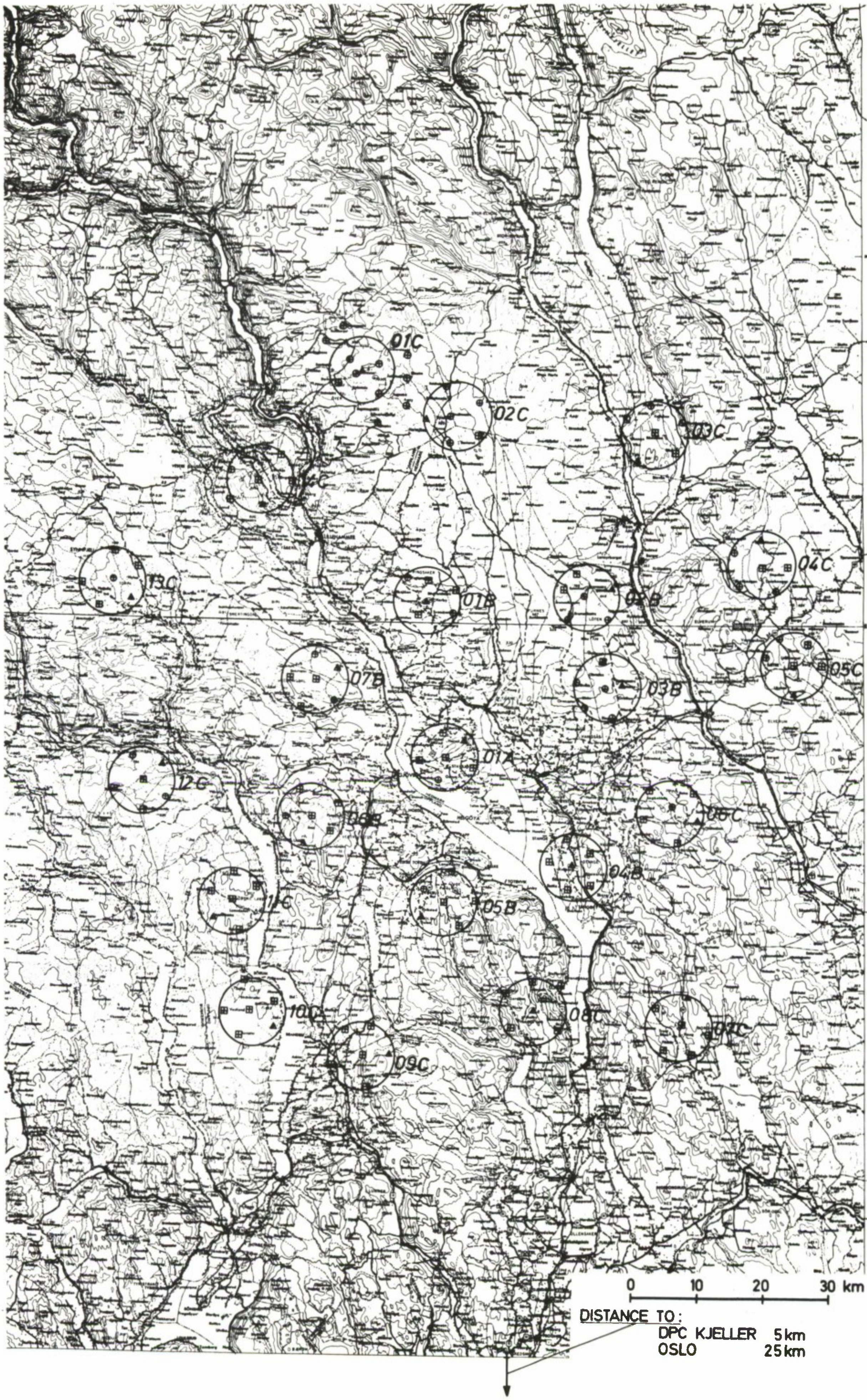


Figure 2.1 NORSAR large seismic array

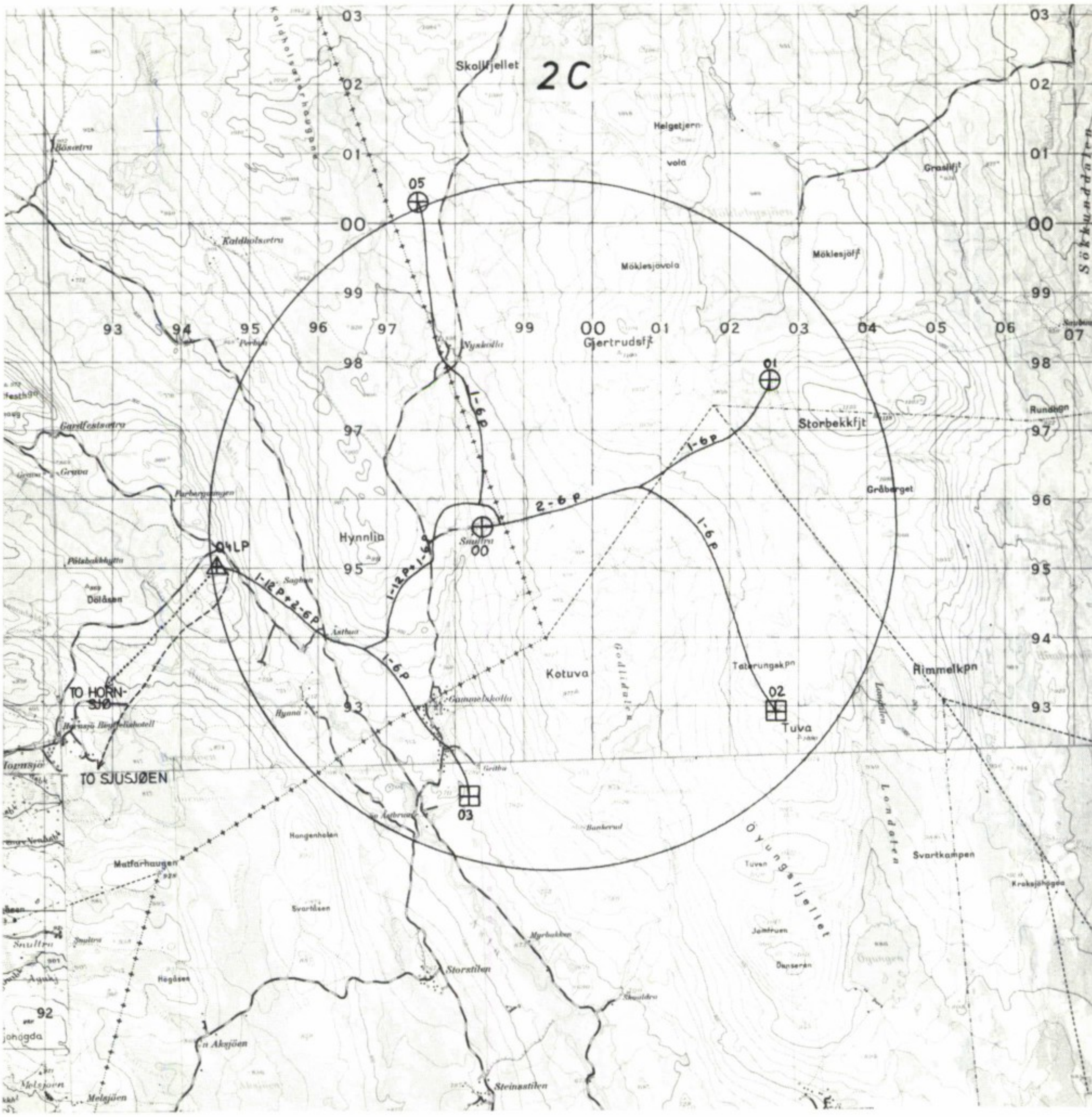


Figure 2.2 <u>Subarray 02C, final configuration</u>

Δ Central area (LP) site	——— Cable trench
□ Shallow (blasted) SP hole	····● Power line
○ Deep (drilled) SP hole	----● Telephone/data link

(NB: Do not use plotted points to determine seismic point coordinates. Use coordinate list, Table 2.1.)

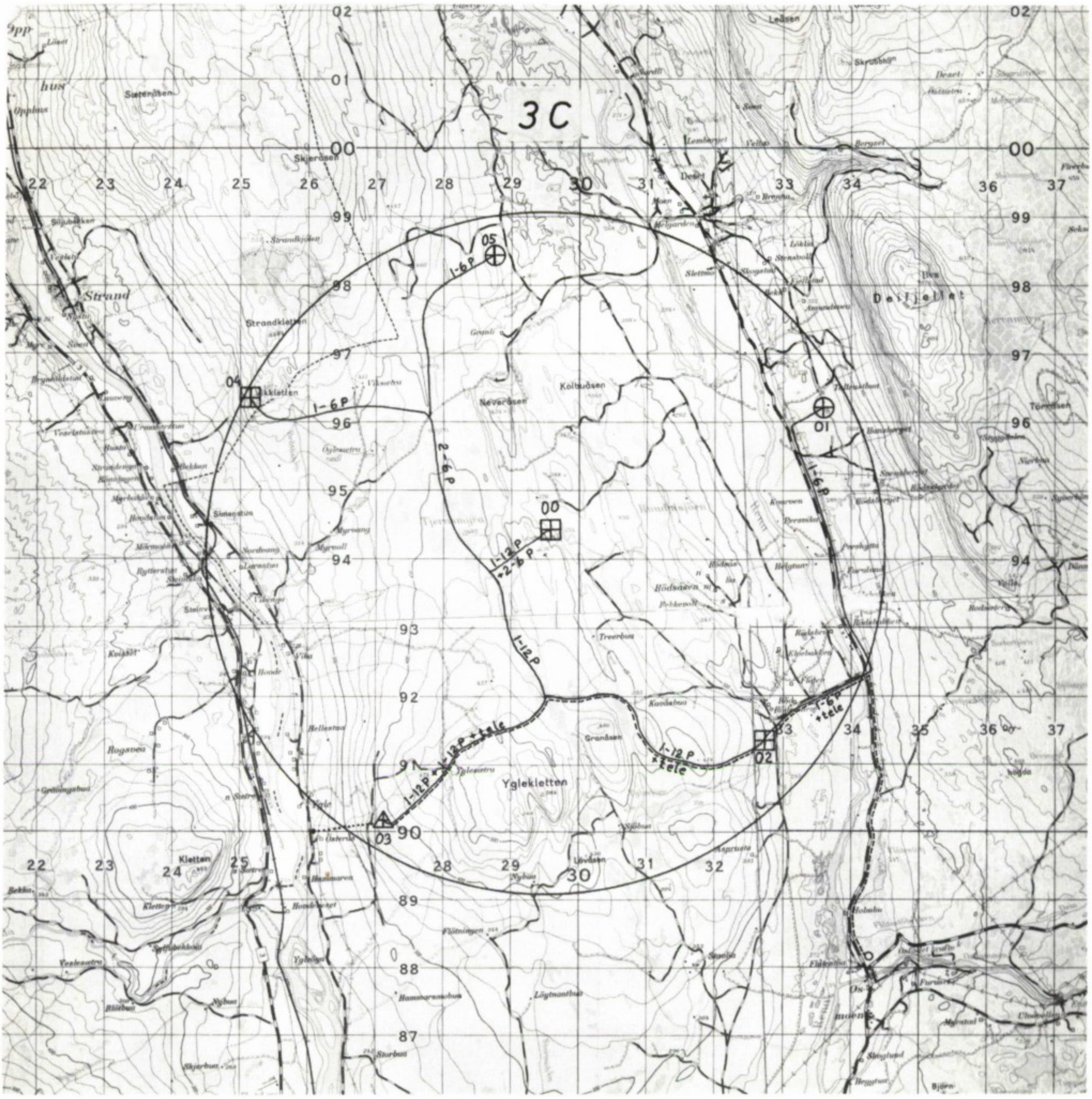


Figure 2.3 Subarray 03C, final configuration

Δ Central area (LP) site	——— Cable trench
□ Shallow (blasted) SP hole	····● Power line
○ Deep (drilled) SP hole	----● Telephone/data link

(NB: Do not use plotted points to determine seismic point coordinates. Use coordinate list, Table 2.1.)

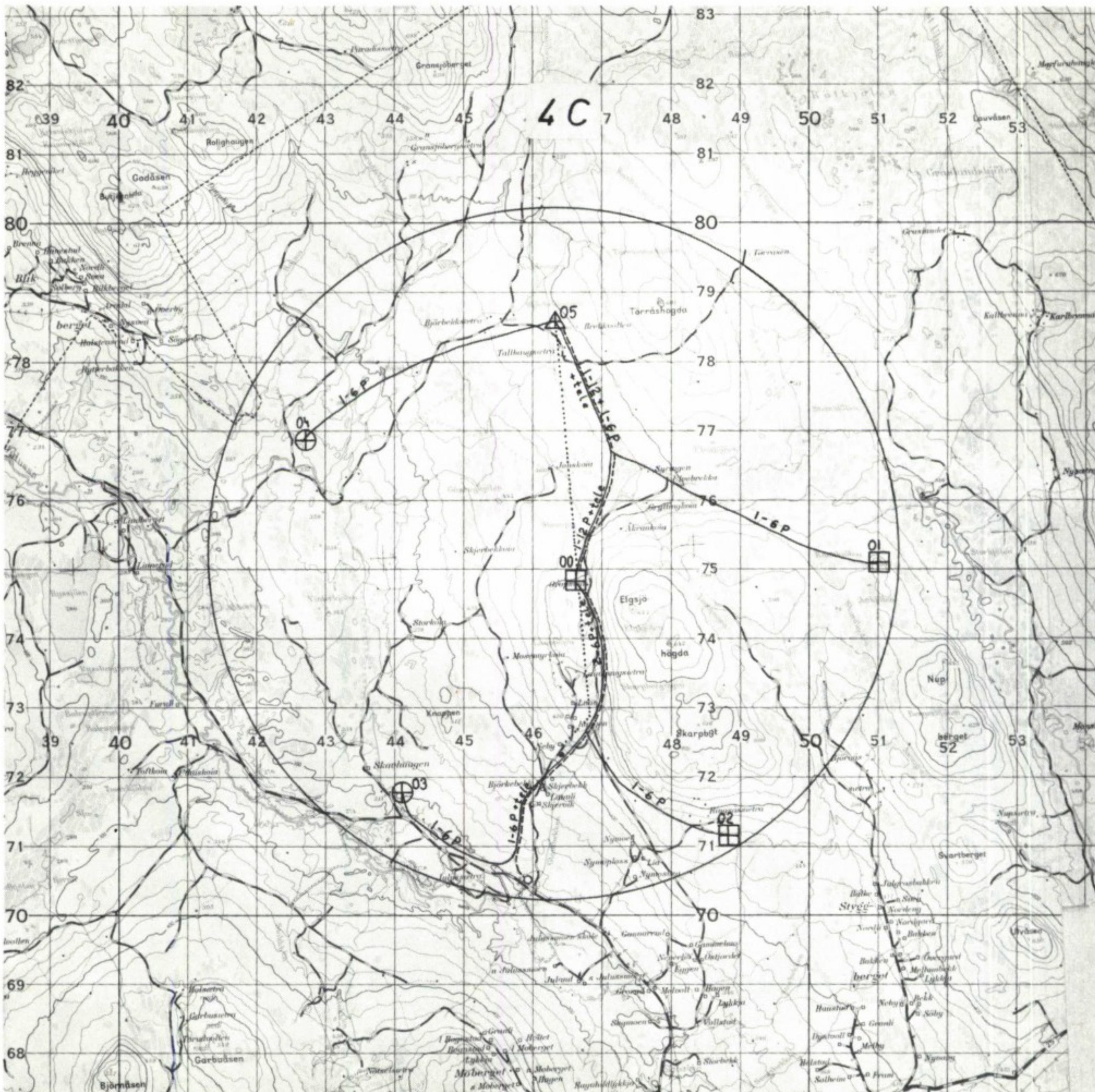


Figure 2.4 Subarray 04C, final configuration

Δ Central area (LP) site ——— Cable trench

□ Shallow (blasted) SP hole ....● Power line

O Deep (drilled) SP hole ----● Telephone/data link

(NB: Do not use plotted points to determine seismic point coordinates. Use coordinate list, Table 2.1.)

Figure 2.5 Subarray 05C, final configuration

Δ Central area (LP) site	——— Cable trench
□ Shallow (blasted) SP hole	. . . .● Power line
○ Deep (drilled) SP hole	- - - -● Telephone/data link

(NB: Do not use plotted points to determine seismic point coordinates. Use coordinate list, Table 2.1.)

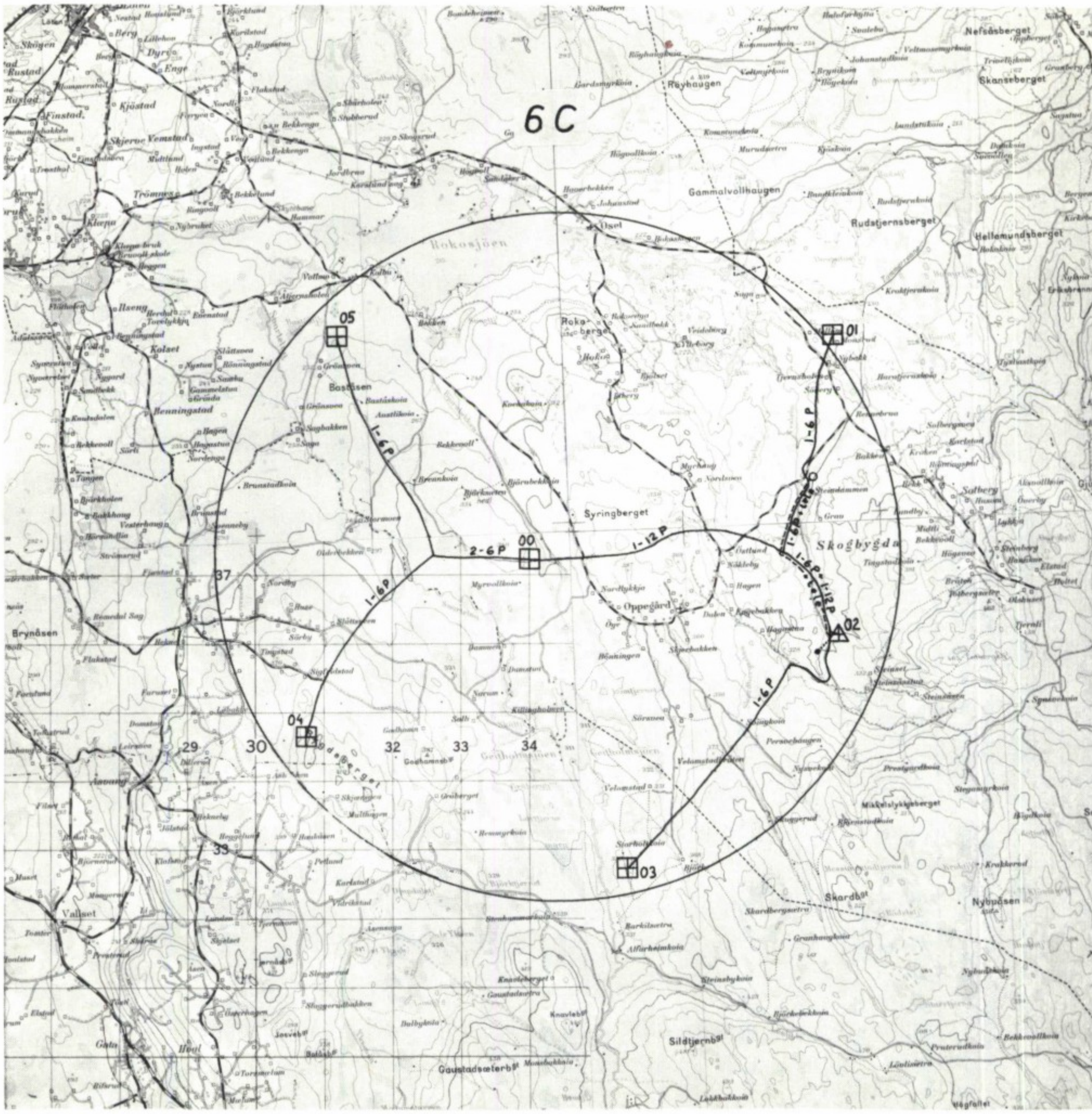


Figure 2.6 <u>Subarray 06C, final configuration</u>

Δ Central area (LP) site —— Cable trench

□ Shallow (blasted) SP hole . . . . ● Power line

○ Deep (drilled) SP hole - - - - ● Telephone/data link

(NB: Do not use plotted points to determine seismic point coordinates. Use coordinate list, Table 2.1.)

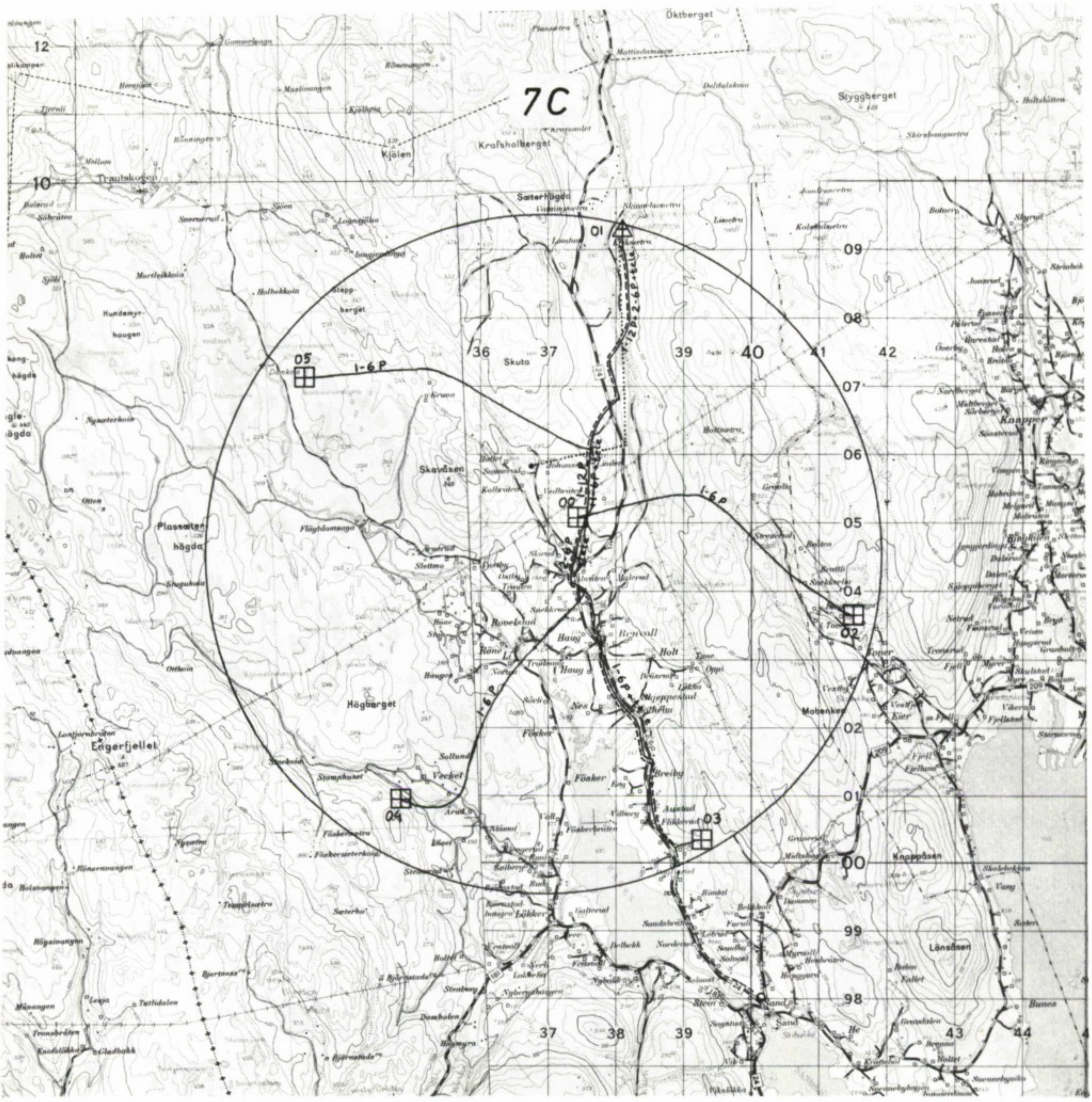


Figure 2.7 Subarray 07C, final configuration

Δ Central area (LP) site	——— Cable trench
□ Shallow (blasted) SP hole	····● Power line
O Deep (drilled) SP hole	----● Telephone/data link

(NB: Do not use plotted points to determine seismic point coordinates. Use coordinate list, Table 2.1.)

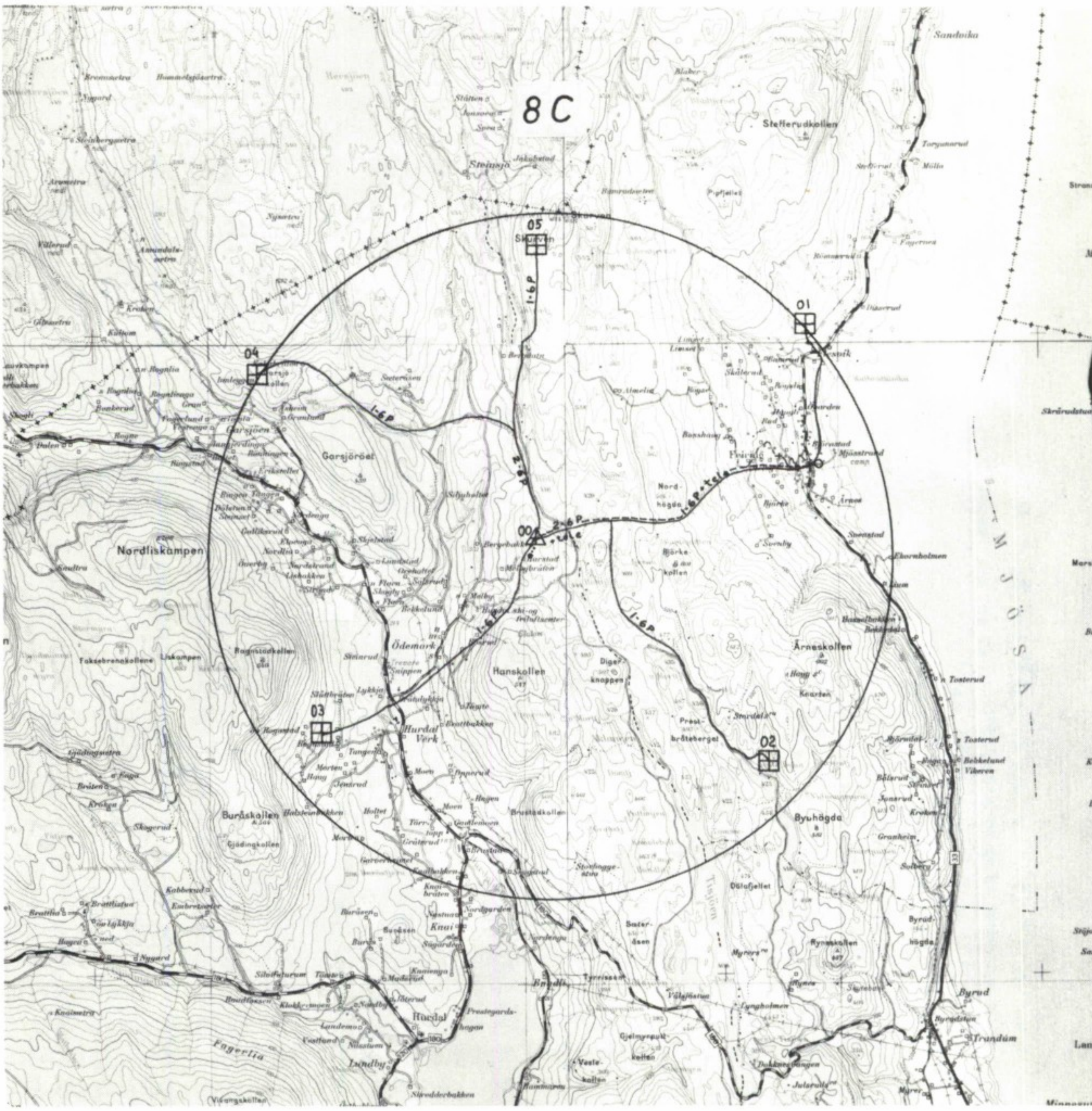


Figure 2.8 Subarray 08C, final configuration

Δ Central area (LP) site	——— Cable trench
□ Shallow (blasted) SP hole	····● Power line
○ Deep (drilled) SP hole	----● Telephone/data link

(NB: Do not use plotted points to determine seismic point coordinates. Use coordinate list, Table 2.1.)

Figure 2.9 Subarray 09C, final configuration

Δ Central area (LP) site —— Cable trench

□ Shallow (blasted) SP hole ····● Power line

O Deep (drilled) SP hole ----● Telephone/data link

(NB: Do not use plotted points to determine seismic point coordinates. Use coordinate list, Table 2.1.)

Figure 2.10 Subarray 10C, final configuration

Δ Central area (LP) site	——— Cable trench
□ Shallow (blasted) SP hole	····● Power line
○ Deep (drilled) SP hole	----● Telephone/data link

(NB: Do not use plotted points to determine seismic point coordinates.
Use coordinate list, Table 2.1.)

Figure 2.11 Subarray 11C, final configuration

Δ Central area (LP) site	——— Cable trench
□ Shallow (blasted) SP hole	····● Power line
○ Deep (drilled) SP hole	----● Telephone/data link

(NB: Do not use plotted points to determine seismic point coordinates. Use coordinate list, Table 2.1.)

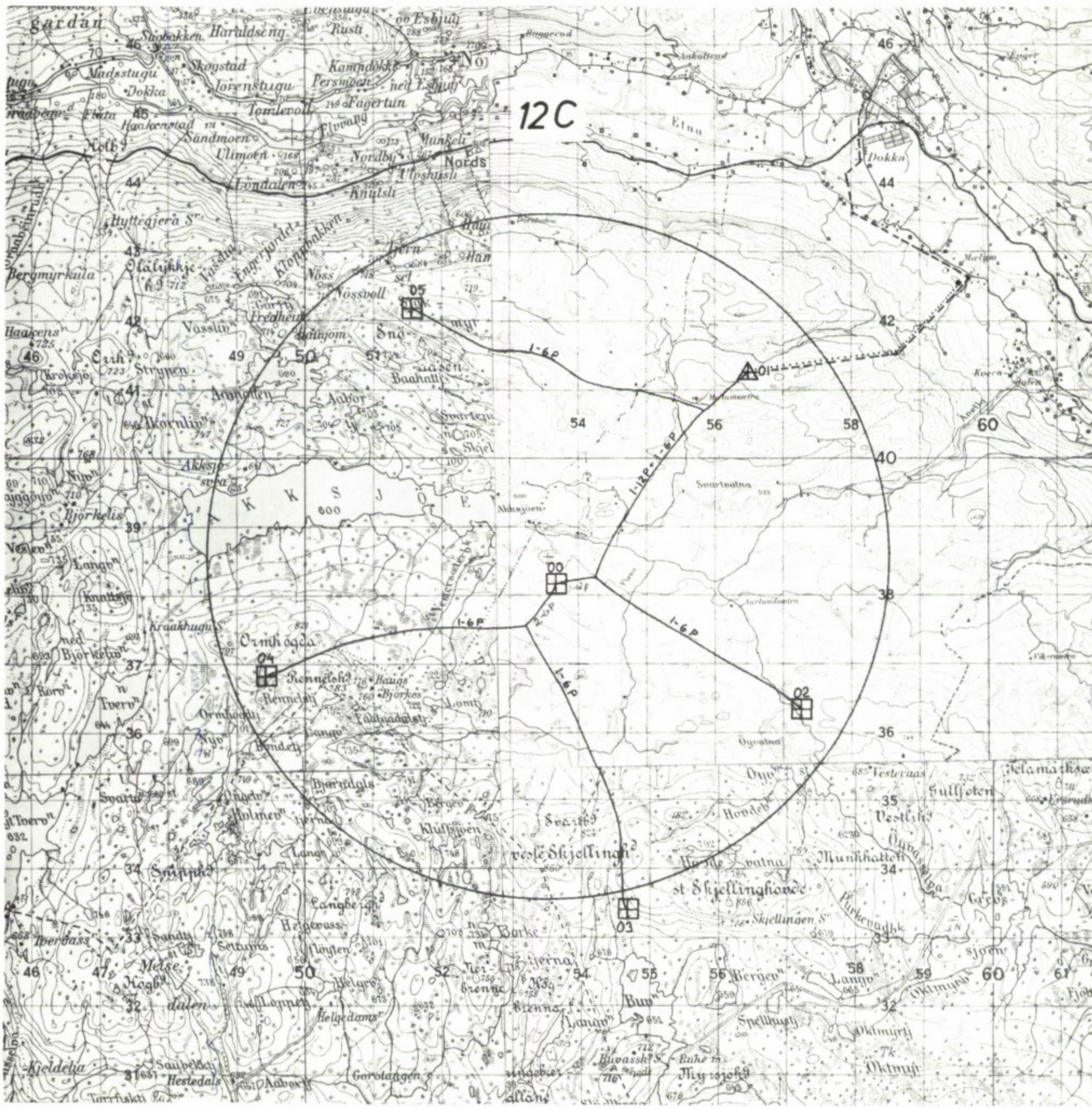


Figure 2.12 Subarray 12C, final configuration

Δ Central area (LP) site ——— Cable trench

□ Shallow (blasted) SP hole · · · ·● Power line

○ Deep (drilled) SP hole - - - -● Telephone/data link

(NB: Do not use plotted points to determine seismic point coordinates. Use coordinate list, Table 2.1.)

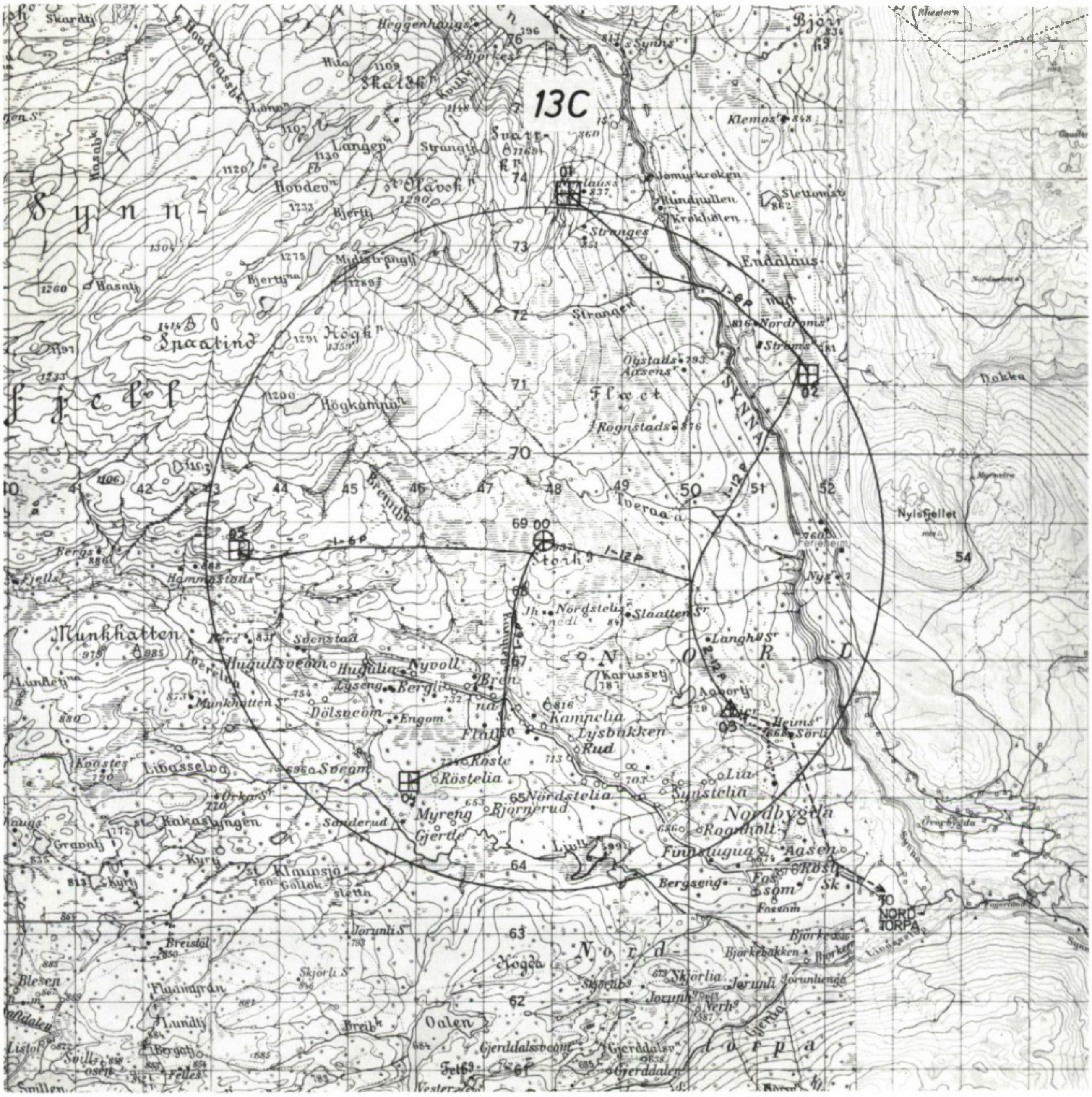


Figure 2.13 Subarray 13C, final configuration

Δ Central area (LP) site

□ Shallow (blasted) SP hole

○ Deep (drilled) SP hole

——— Cable trench

. . . .● Power line

- - - -● Telephone/data link

(NB: Do not use plotted points to determine seismic point coordinates. Use coordinate list, Table 2.1.)

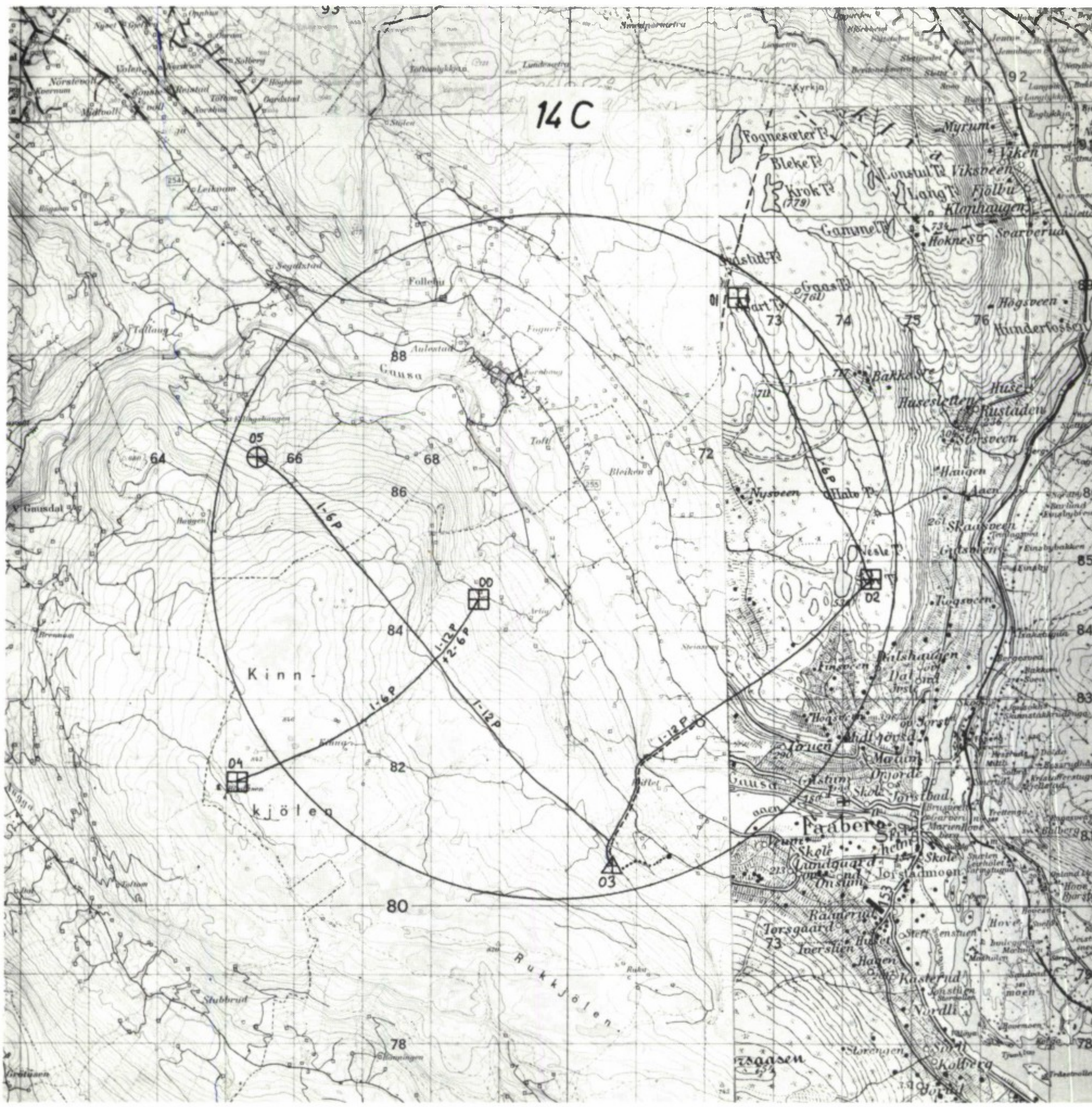


Figure 2.14 Subarray 14C, final configuration

△ Central area (LP) site —— Cable trench
□ Shallow (blasted) SP hole ....● Power line
○ Deep (drilled) SP hole ----● Telephone/data link

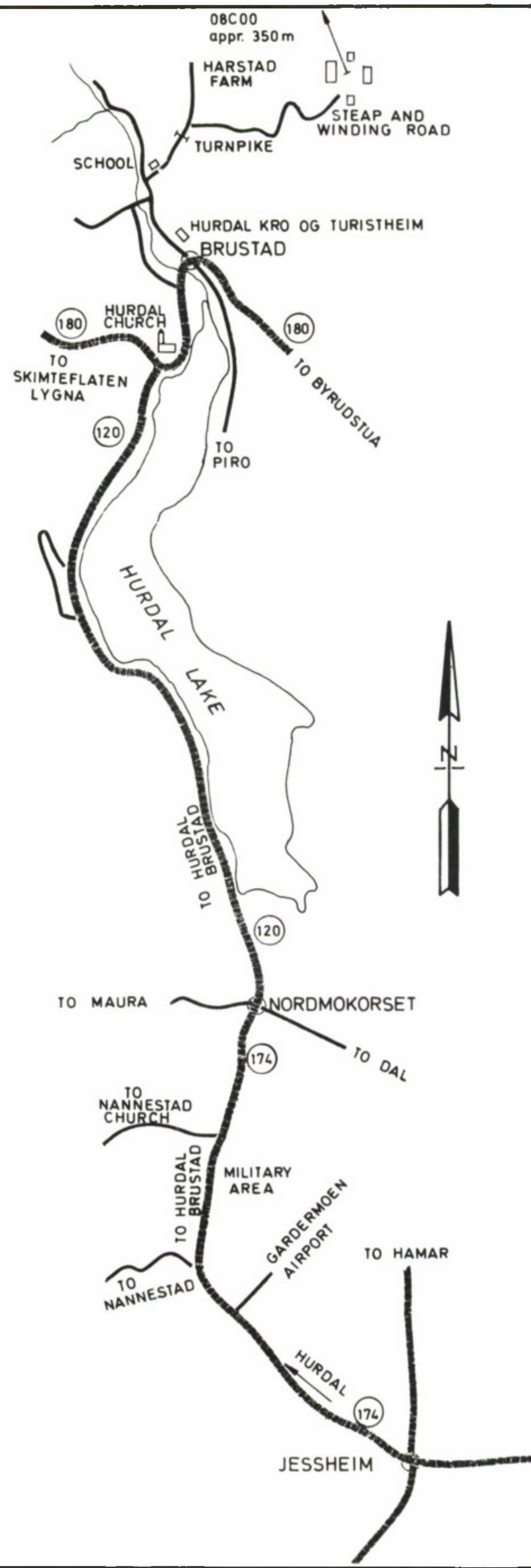
(NB: Do not use plotted points to determine seismic point coordinates. Use coordinate list, Table 2.1.)

	ROUTE
OSLO - JESSHEIM	E 6
JESSHEIM - NORDMOKORSET	174
NORDMOKORSET - HURDAL CHURCH	120
HURDAL CHURCH - BRUSTAD	180

From BRUSTAD follow county road to blue road sign marked "HURDAL SKI-OG FRILUFTSENTER". (Primary school on right hand.) Follow this road to turnpike. First road right after the turnpike to the farm HARSTAD. Site 08C00 is located appr. 350 m NE of the farm.

	VEI NR.
OSLO - JESSHEIM	E 6
JESSHEIM - NORDMOKORSET	174
NORDMOKORSET - HURDAL KIRKE	120
HURDAL KIRKE - BRUSTAD	180

Fölg fylkesvei fra BRUSTAD til blått veiskilt "HURDAL SKI- OG FRILUFTSENTER". (Folkeskole på höyre side.) Fölg veien til bommen. Etter bommen förste vei til höyre til HARSTAD gård. 08C00 ligger ca. 350 m NÖ for gården.



SKISSE FOR ADKOMST TIL 08C00 HURDAL

Figure 2.15 Example of access description for seismic point

2.4 Land acquisition

One of the main reasons for starting the siting as early as possible was to allow reasonable time for the land acquisition people (under the Defence Construction Services of the Norwegian DOD) to contact and obtain permission from the landowners involved. An agreement had to be presented to and signed by the landowner before any constructional work could start.

Since hundreds of landowners were affected, the land acquisition (l a) job was given very high priority. At times the l a staff had to base its work on rather preliminary siting of seismic points and cable routes. In some cases this led to dealings with landowners who later turned out to be unaffected by any of the installations. On the other hand, the final siting and routing sometimes brought in new landowners, and necessitated further field acquisition trips.

By the middle of May 1969, enough permissions had been obtained from landowners to be able to start construction on subarrays 06C and 07C. This corresponded well with the starting date proposed in a progress schedule (Figure 3.1) prepared by the consultants. The schedule stipulated that the starting dates for the remaining subarrays should be distributed about evenly within a period lasting until the beginning of July, when construction was to commence on the last subarray, 12C. In no case was the progress seriously hampered by lack of permission from a landowner, a good record considering the number of landowners (approx 340) affected by the 1969 building program.

Not unexpectedly, the settlement of the economic compensations to the landowners proved to be much more time-consuming than collecting the work permissions. As of today (February 1971) some 550 out of a total of 670 landowners from the A- B- and C-rings have been paid, leaving about 120 landowners to deal with. Most of these damage claims will probably be settled normally, but one may expect a few delays due to a not uncommon hesitancy among the landowners to accept the first damage settlement offered.

In some cases, however, landowners have not accepted the amount of compensation proposed by the land valuer, and these have to be solved by judicial valuation. Since this must be based on special surveys of the contested sites, these cases cannot be dealt with until summer 1971, when snow has melted.

3 CONSTRUCTION OF VAULTS AND SEISMOMETER HOLES

3.1 Modifications relative to the 1968 designs

Experience gathered during the winter season 1968/69 revealed a few shortcomings in the vault and WHV designs. A main objection was the difficult access into the CTV and WHV. This was due to the very heavy timber lids used as top cover for these installations (see (2), Figures 4.3 and 5.8). The lids were hard to handle in summertime, and even more so during the winter, when snow and ice added to the difficulties.

Figure 3.2 shows the new CTV lid design. Compared with the 1968 design, the most radical modification is that the lid has been divided into two parts.

There was little sense in dividing the WHV lid, but it proved possible to lessen the weight by nearly 50% by reducing the lid dimensions (Figure 3.3).

It was also decided to give the top surface of the lids an anti-skid finish.

3.2 Construction

The methods used in construction did not differ much from those described in (2), chapters 4 and 5. Some of the 1968 WHVs were placed too high relative to the surrounding terrain, the exposed high walls tending to increase the coupling of wind noise down to the seismometer. The geologists and building inspectors were therefore specially instructed to ensure that the blasting gave deep enough holes to hide most of the superstructure.

In some areas it proved impossible to find rock outcrops suitable for a shallow hole. A deep hole through overburden and down 3 meters into the bedrock had to be used. Experience from 1968 had shown that it is very difficult to estimate the overburden depth from an examination of the surface only. At the same time it was desirable that the hole depth should not exceed 10 m, the cost and drilling time would increase rapidly beyond that depth. Based on a suggestion from the geology consultants, it was decided that all overburden sites should be sounded by means of test drillings, based on special light-weight drill rigs using small-bore drillbits. This turned out to save time and money.

The construction work started in the middle of May 1969 and all major constructional tasks were completed by week 41, i e in the first part of October, some 14 days later than stipulated in the Progress Schedule of 2 June 1969.

Figures 3.4 through 3.16 show layout maps of the C-ring central areas. An example of a drilling report is shown in Figure 3.17.

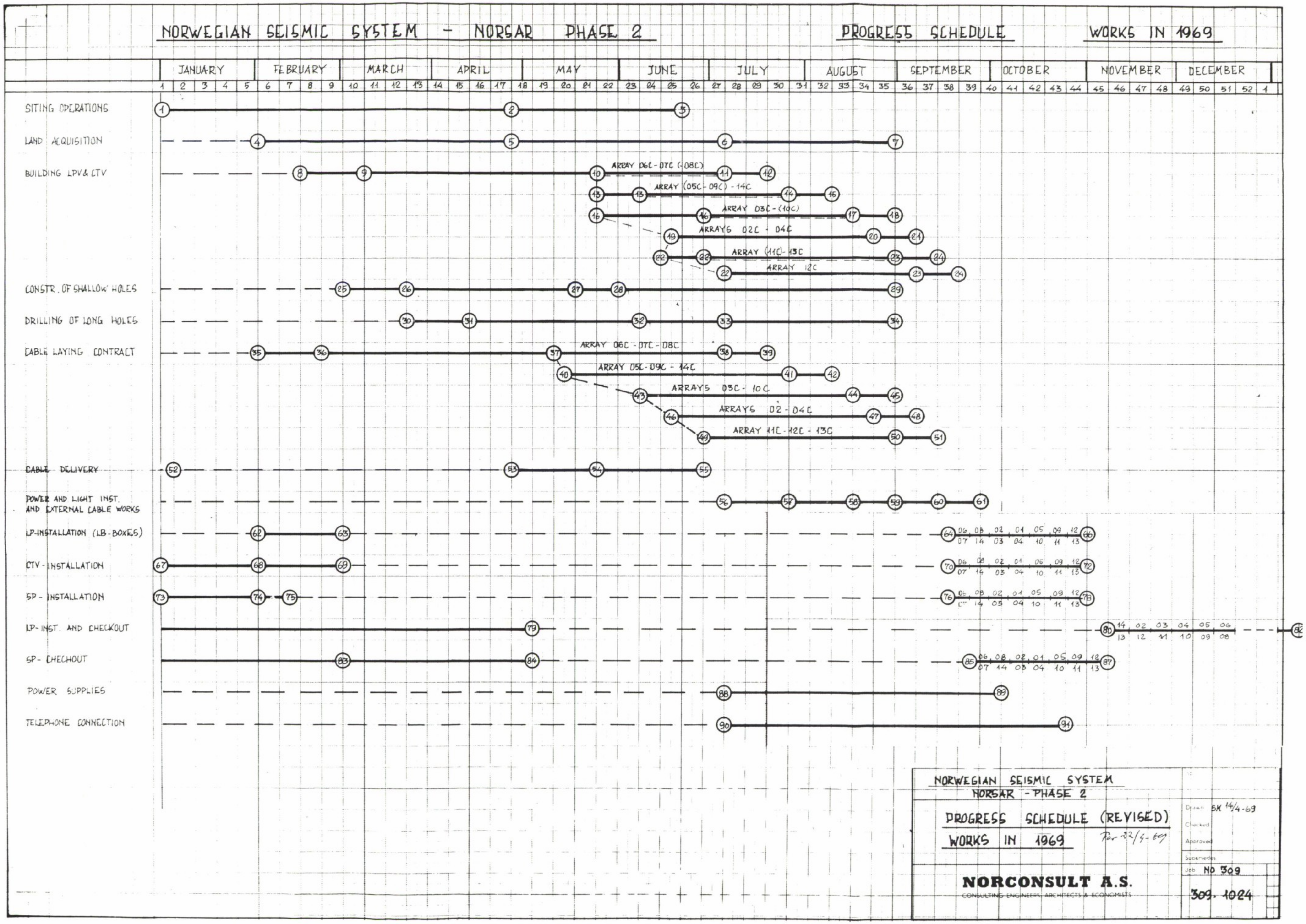


Figure 3.1 Progress schedule 1969

NORCONSULT A.S. Høvik, 15th April, 1969

NORWEGIAN SEISMIC SYSTEM - NORSAR - PHASE 2

KEY TO

REVISED PROGRESS SCHEDULE - WORKS IN 1969

1. Siting for six first arrays completed and land owner lists delivered.
2. Siting for all arrays completed and l.o.lists delivered.
3. Revision of l.o. lists and cable routes completed.
4. Land acquisition start for 6 first arrays.
5. Land requisition for 3 first arrays completed.
6. Land requisition completed, working permits given.
7. Land requisition contracts signed.
8. Tenders out for building of LPV and CTV.
9. Tenders in for building of LPV and CTV.
10. Contracts signed and work start with vaults in arrays 07C-08C-14C.
11. Ready for installation in vaults.
12. Contract work completed and inspected.
13. Work start with vaults in arrays 05C-06C-09C.
14. Ready for installation in vaults.
15. Contract work completed and inspected.
16. Work start with vaults in arrays 03C-10C.
17. Ready for installation in vaults.
18. Contract work completed and inspected.
19. Work start with vaults in arrays 02C-04C.
20. Ready for installation in vaults.
21. Contract work completed and inspected.
22. Work start with vaults in arrays 11C-12C-13C.
23. Ready for installation in vaults.
24. Contract work completed and inspected.
25. Tenders out for construction of shallow holes.
26. Tenders in for shallow holes.
27. Contracts signed and work start with shallow holes.
28. First shallow hole completed and ready for installation.
29. All shallow holes completed and ready for installation.
30. Tenders out for construction of long holes.
31. Tenders in for long holes.
32. Contract signed and work start for long holes.
33. First long hole completed and ready for installation.
34. Long holes completed and ready for installation.
35. Tenders out for trenching and cable laying.
36. Tenders in for trenching and cable laying.
37. Contracts signed and work start with trenches in 07C-08C-14C.
38. Work completed and ready for installation.
39. Contract work completed and inspected.
40. Work start with trenches in 05C-06C-09C.
41. Work completed and ready for installation.
42. Contract work completed and inspected.
43. Work start with trenches in 03C-10C.
44. Work completed and ready for installation.
45. Contract work completed and inspected.
46. Work start with trenches in 02C-04C.
47. Work completed and ready for installation.
48. Contract work completed and inspected.
49. Work start with trenches in 11C-12C-13C.
50. Work completed and ready for installation.
51. Contract work completed and inspected.
52. 210 km 6 pair cable stored for 1969 program.
53. Delivery of 12 pair cables start.
54. Delivery of 12 pair cables completed and delivery of 6 pair cable start.
55. All remaining 6 pair cable delivered.
56. Power and light installation start for LPV-CTV in 07C-08C-14C.
57. Power and light installation start in 05C-06C-09C.
58. Power and light installation start in 03C-10C.
59. Power and light installation start in 02C-04C.
60. Power and light installation start in 11C-12C-13C.
61. Power and light installation in all vaults completed.
62. Installation of LB-boxes in LPV completed for 5 arrays in the 1968 program.
63. Installation of LB-boxes in LPV completed for the 1968 program.
64. Installation of LB-boxes in LPV start for C-arrays.

66. Installation of LB-boxes in all arrays completed.
67. CTV-installation completed for arrays 01A-01B-04B
68. CTV-installation completed for arrays 02B-03B.
69. CTV-installation completed for the 1968 program.
70. CTV-installation start for C-arrays.

72. CTV-installation completed for all arrays.
73. SP-installation completed for arrays 01A-01B-04B
74. SP-installation completed for 02B-03B.
75. SP-installation completed for 1968 program.
76. SP-installation start for C-arrays.

78. SP-installation completed for all arrays.
79. LP-installation and checkout completed for 1968 program.
80. LP-installation and checkout start for C-arrays.

82. LP-installation and checkout completed for all arrays.
83. SP-checkout completed for arrays 01A-01B-04B.
84. SP-checkout completed for 1968 program.
85. SP-checkout start for C-arrays.

87. SP-checkout completed for all arrays.
88. Power Supply completed for 3 first arrays.
89. Power supply completed for all arrays.
90. Telephone connection completed for 3 first arrays.
91. Telephone connection completed for all arrays.

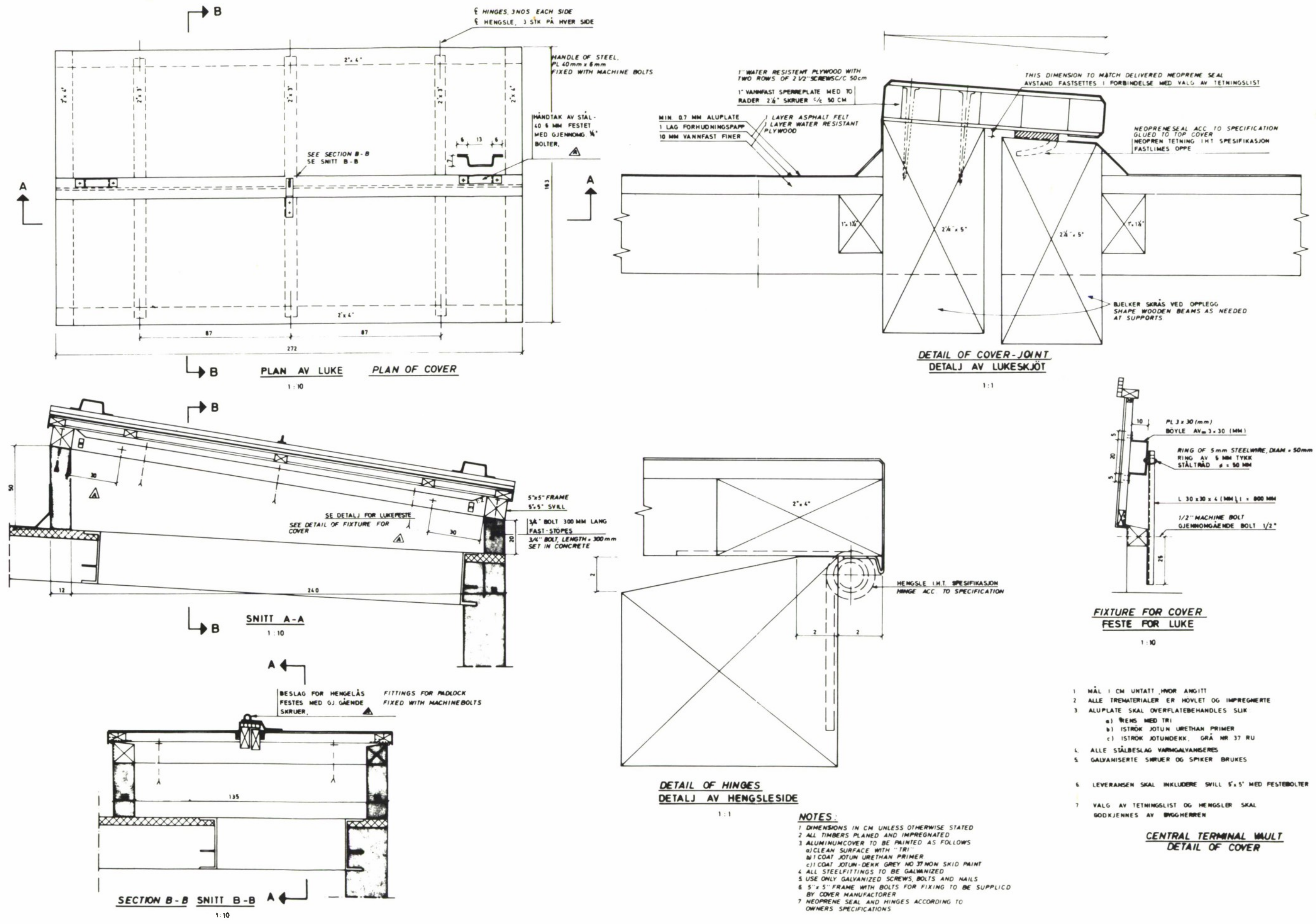


Figure 3.2 Construction drawing of lid, Central Terminal Vault superstructure, C-ring model

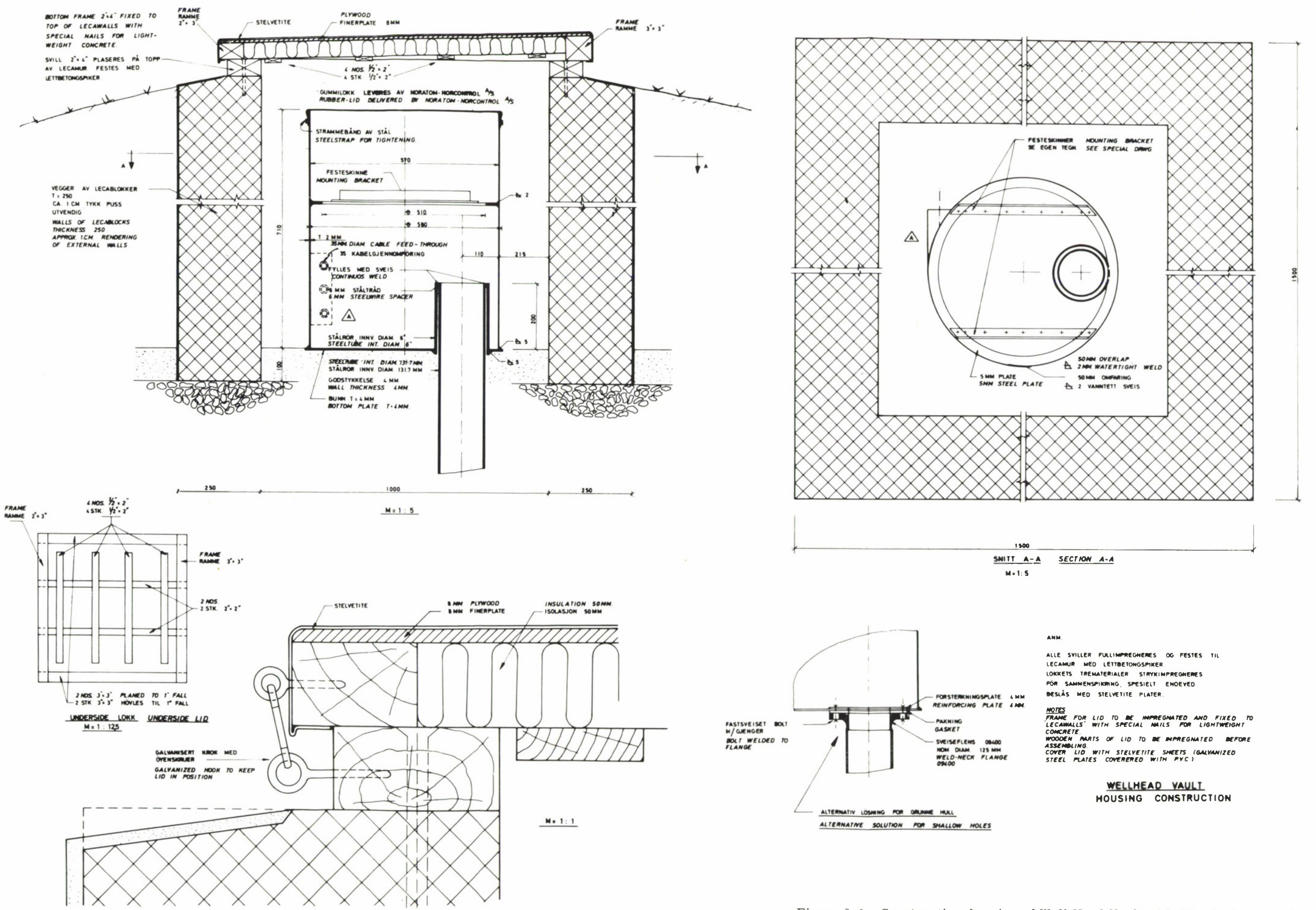


Figure 3.3 Construction drawing of Wall Head Vault with lid, C-ring model

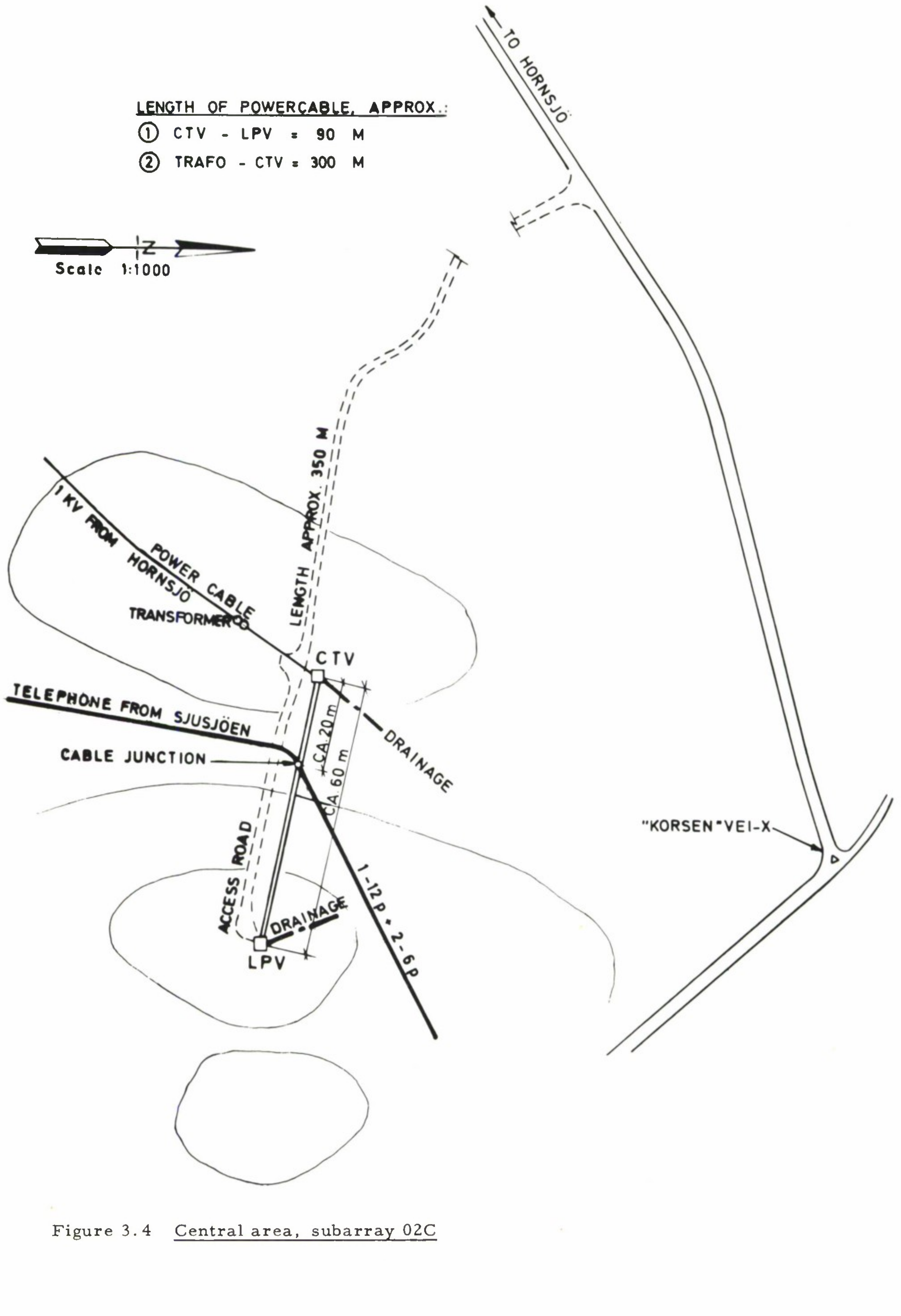


Figure 3.4 Central area, subarray 02C

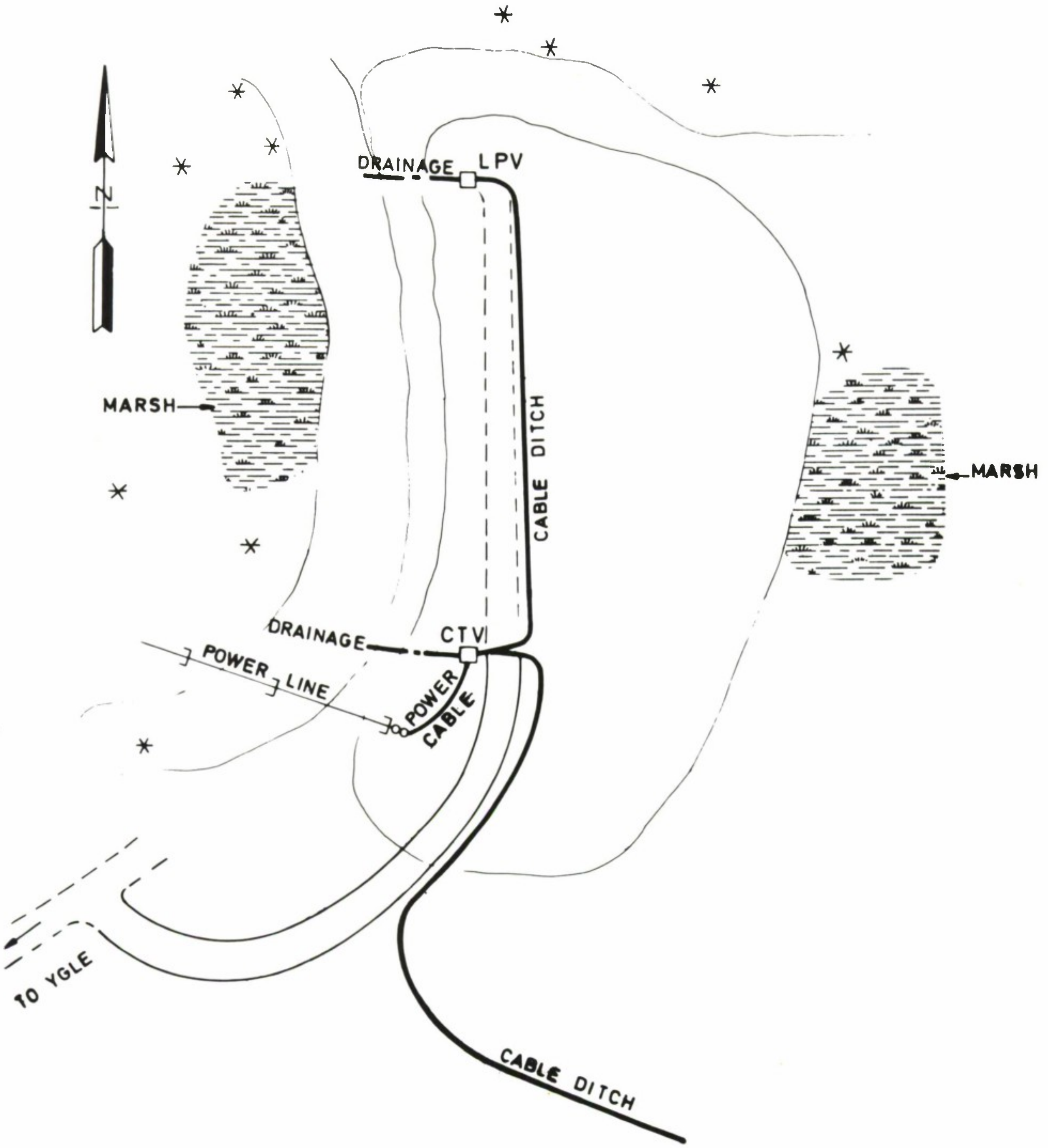


Figure 3.5 Central area, subarray 03C

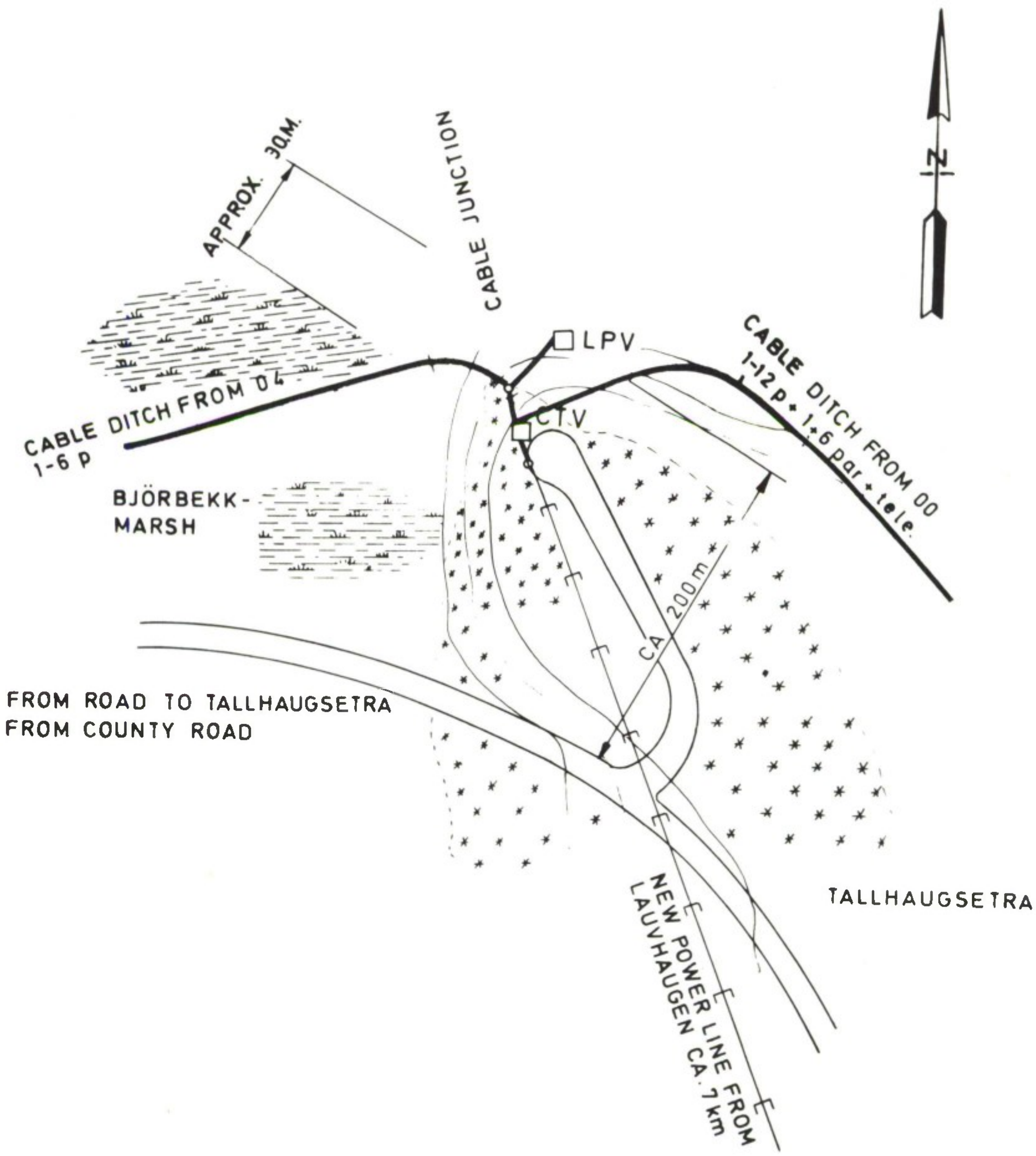


Figure 3.6 Central area, subarray 04C

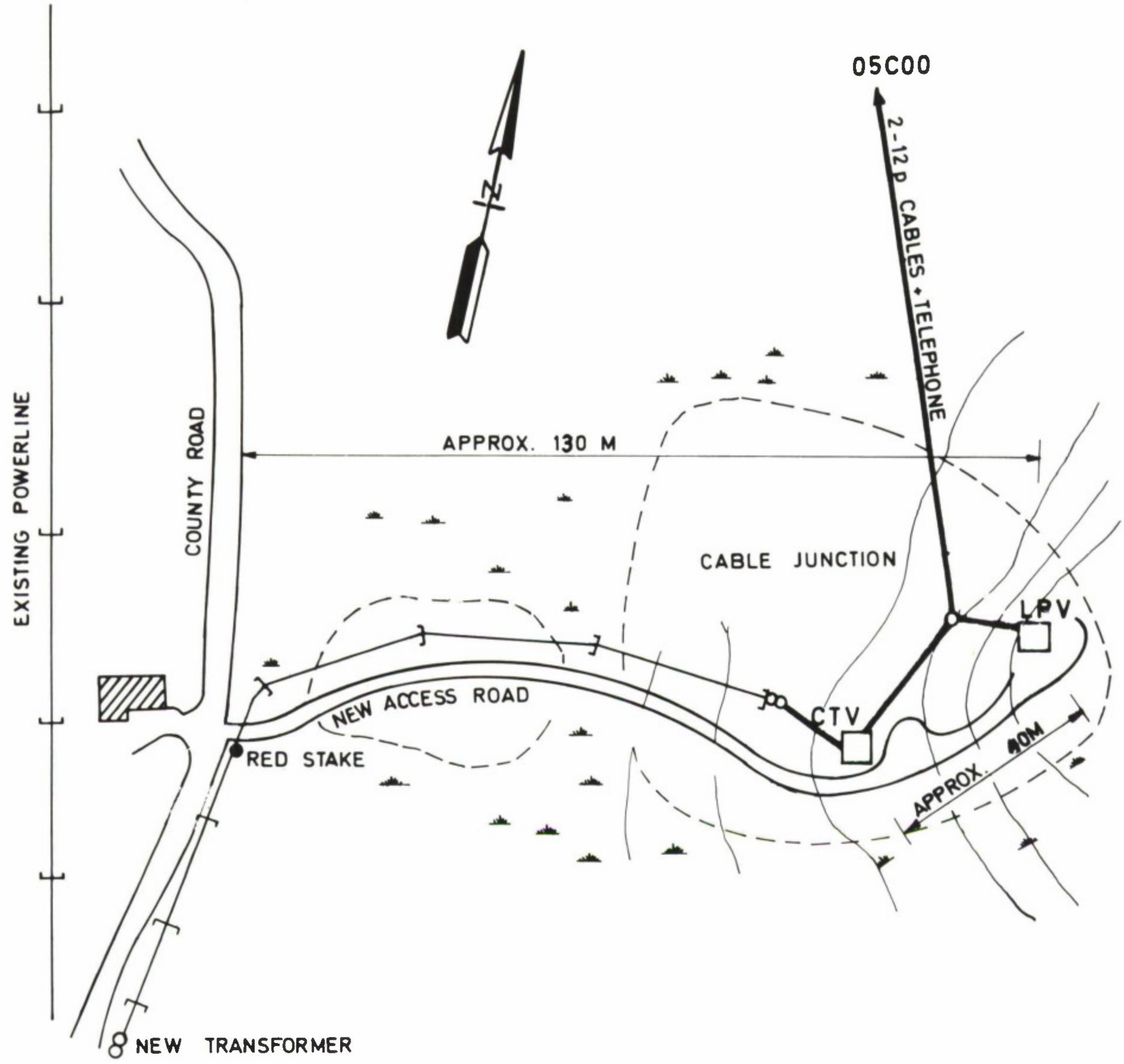


Figure 3.7 Central area, subarray 05C

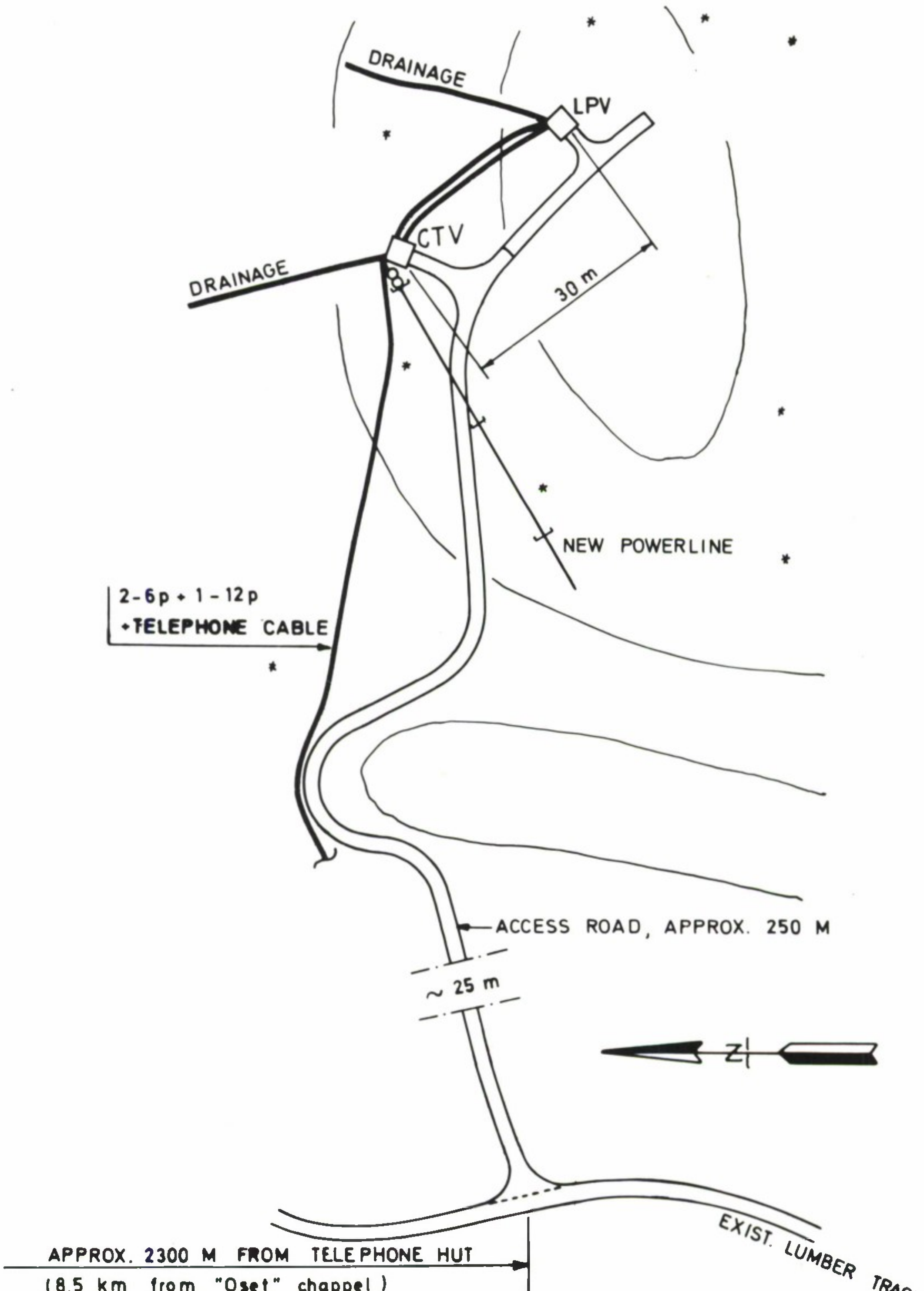


Figure 3.8 Central area, subarray 06C

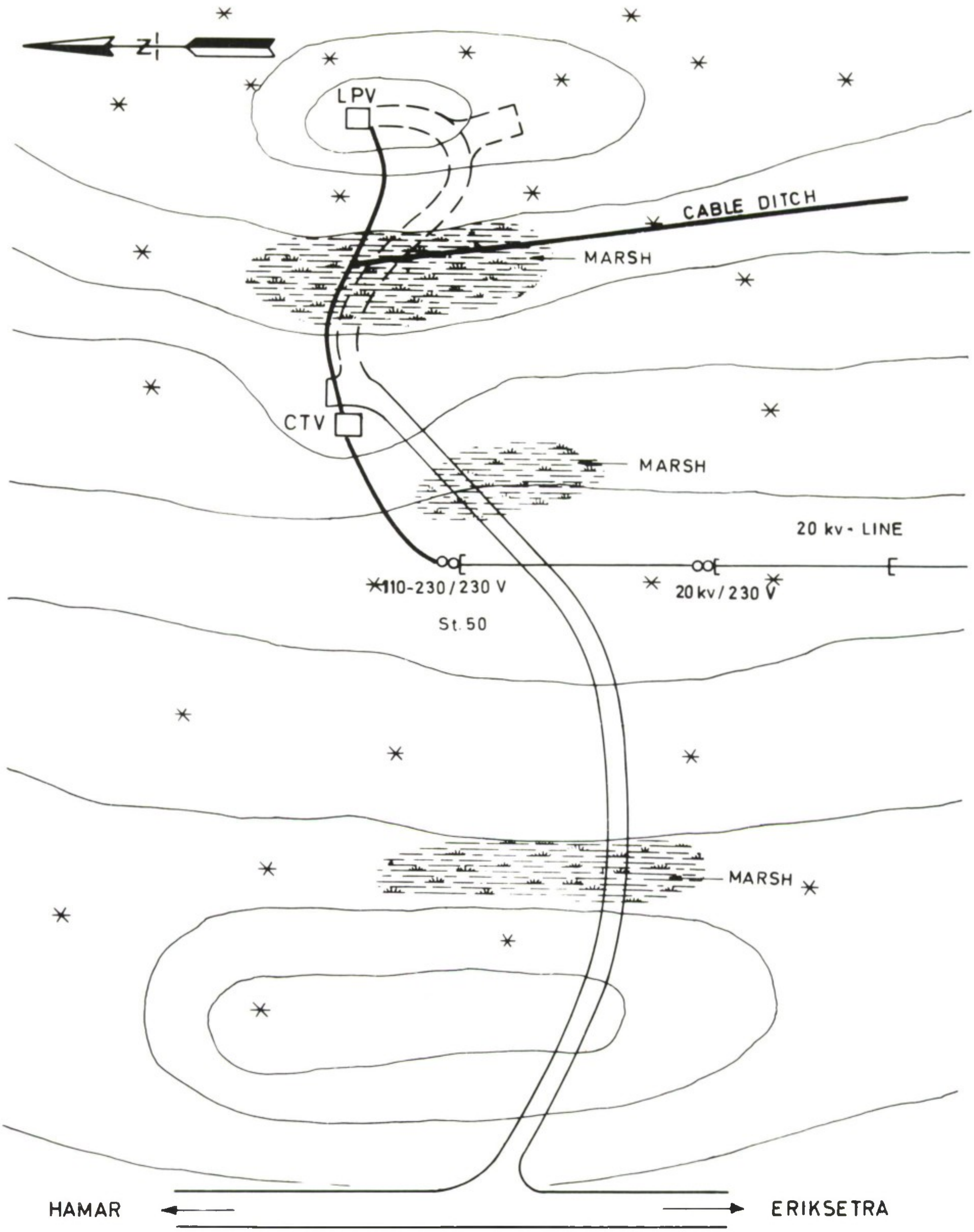


Figure 3.9 Central area, subarray 07C

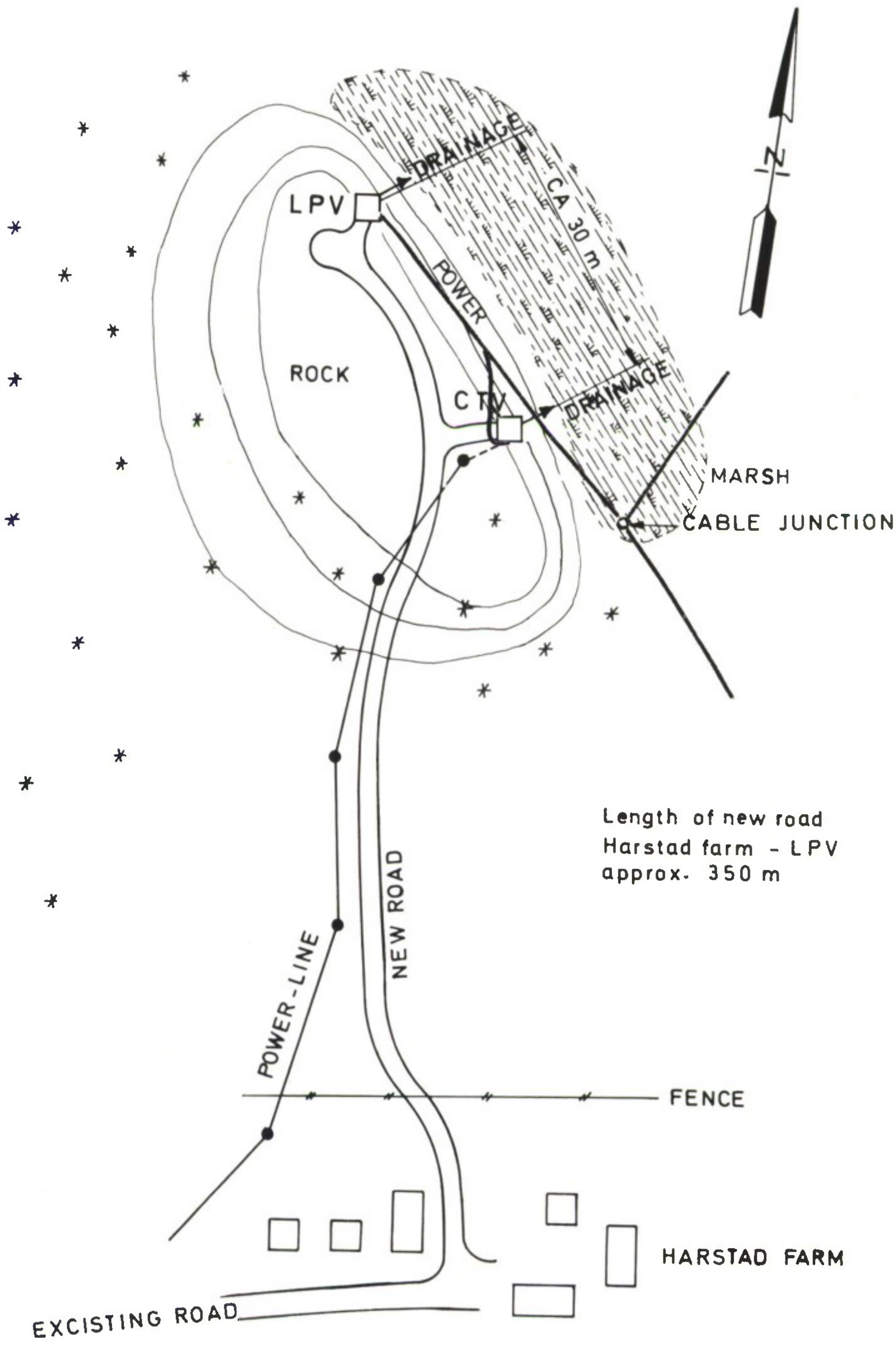


Figure 3.10 Central area, subarray 08C

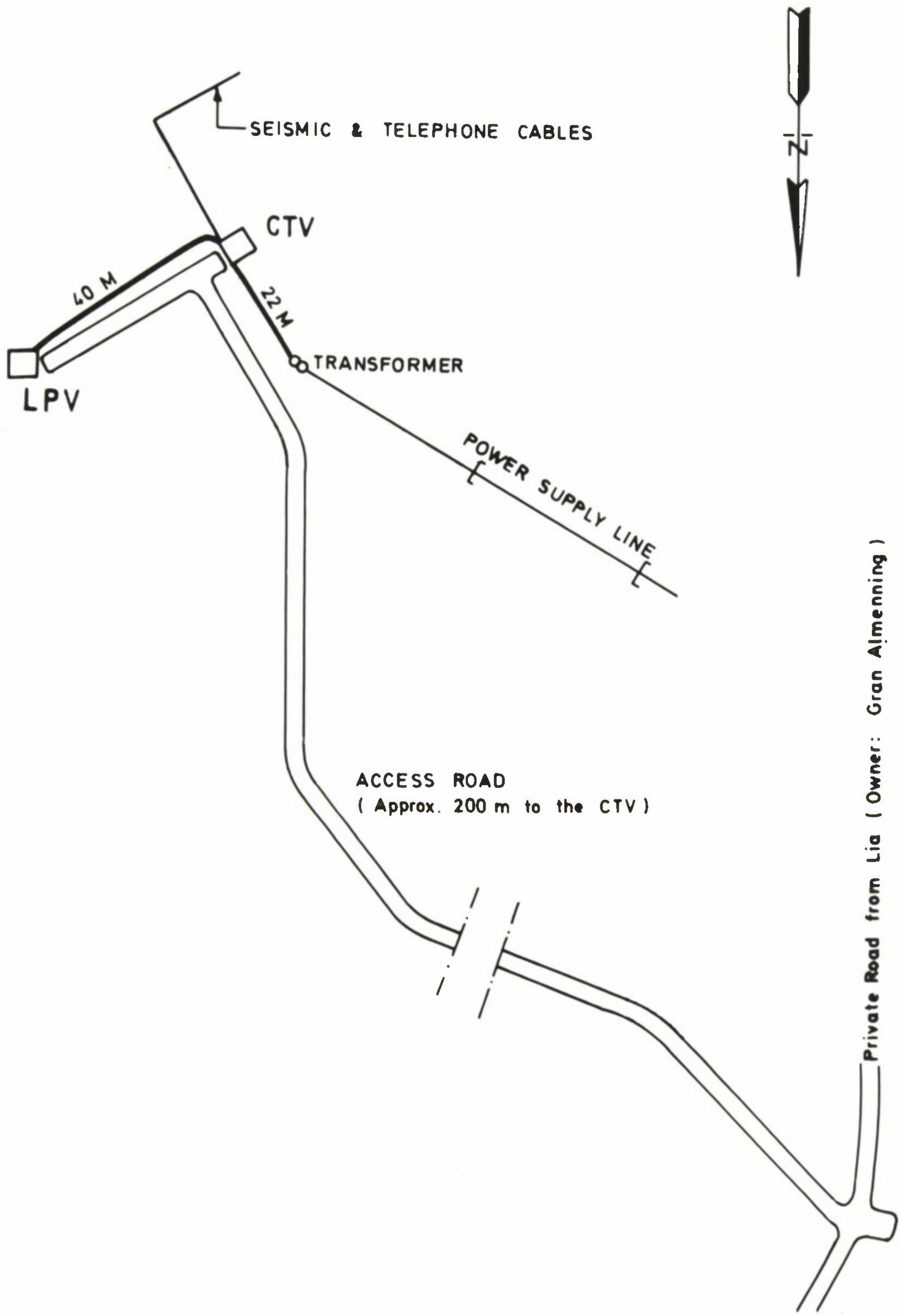


Figure 3.11 Central area, subarray 09C

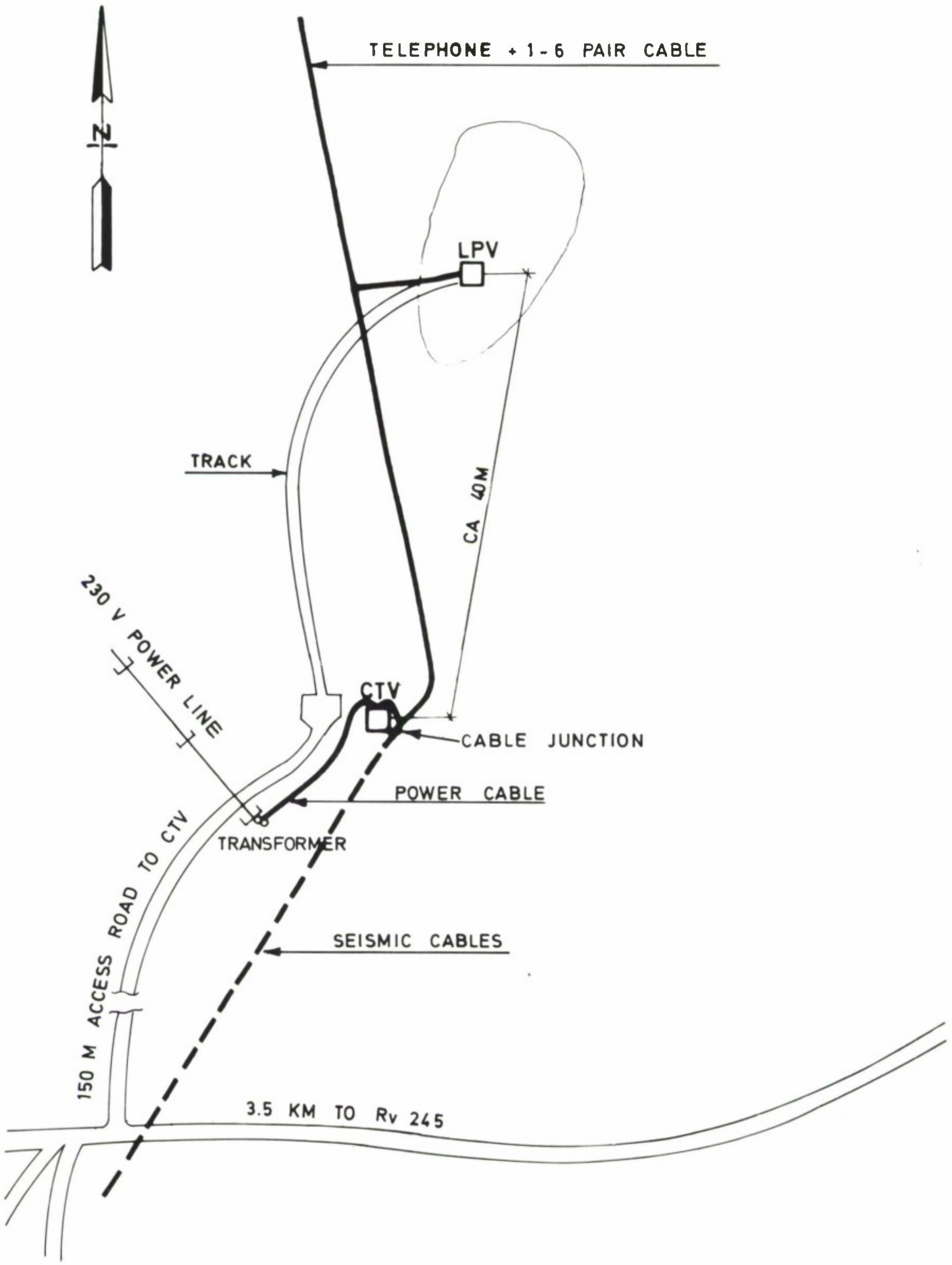


Figure 3.12 Central area, subarray 10C

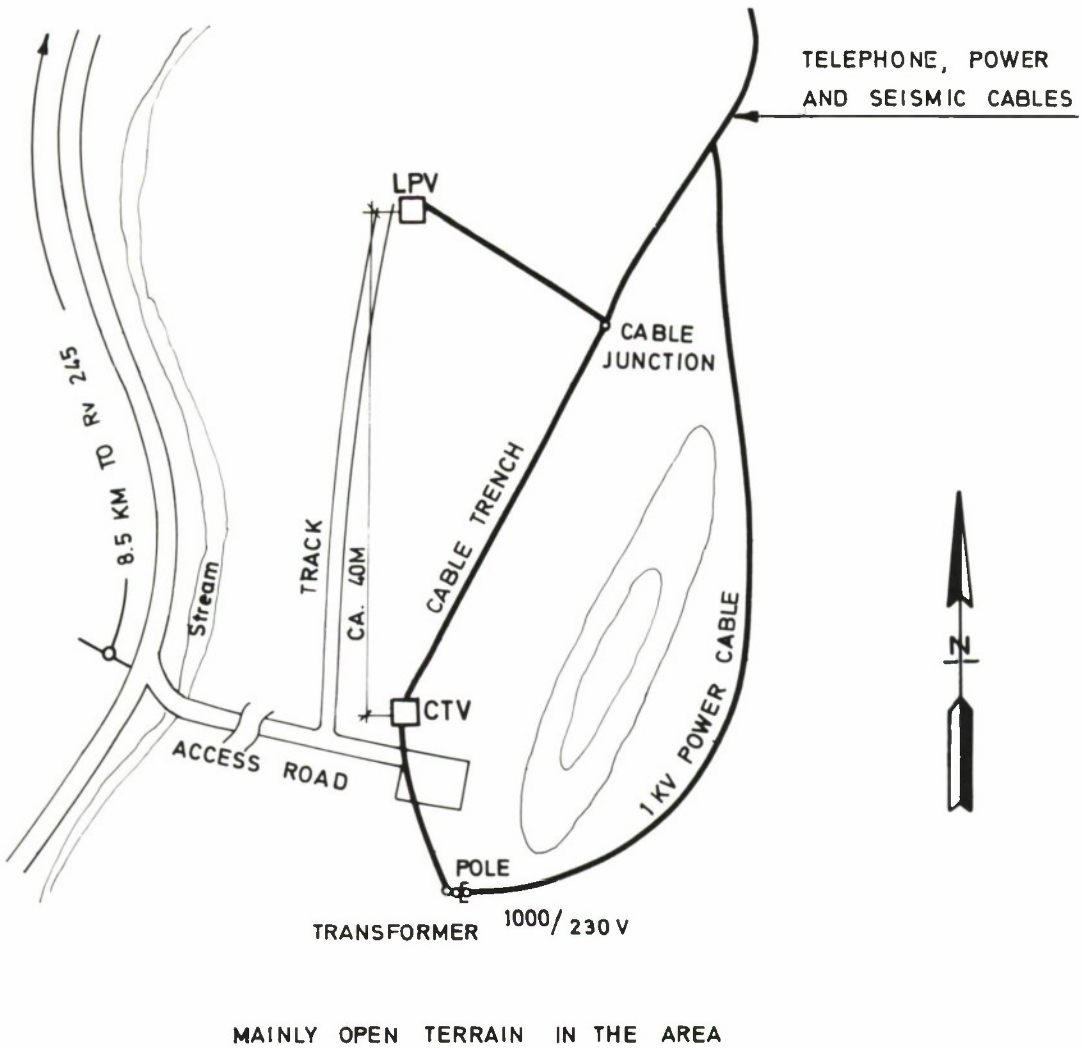


Figure 3.13 Central area, subarray 11C

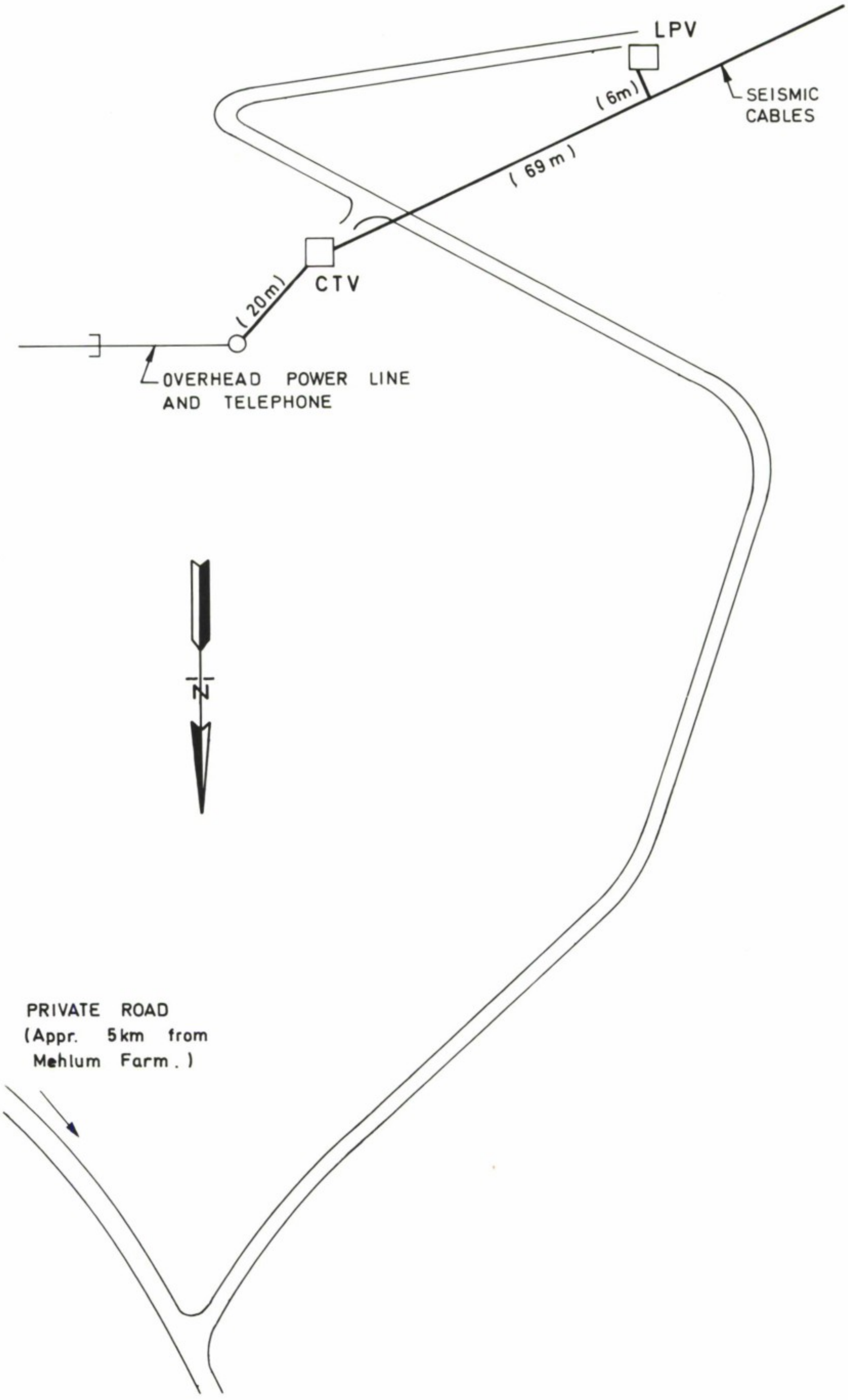


Figure 3.14 Central area, subarray 12C

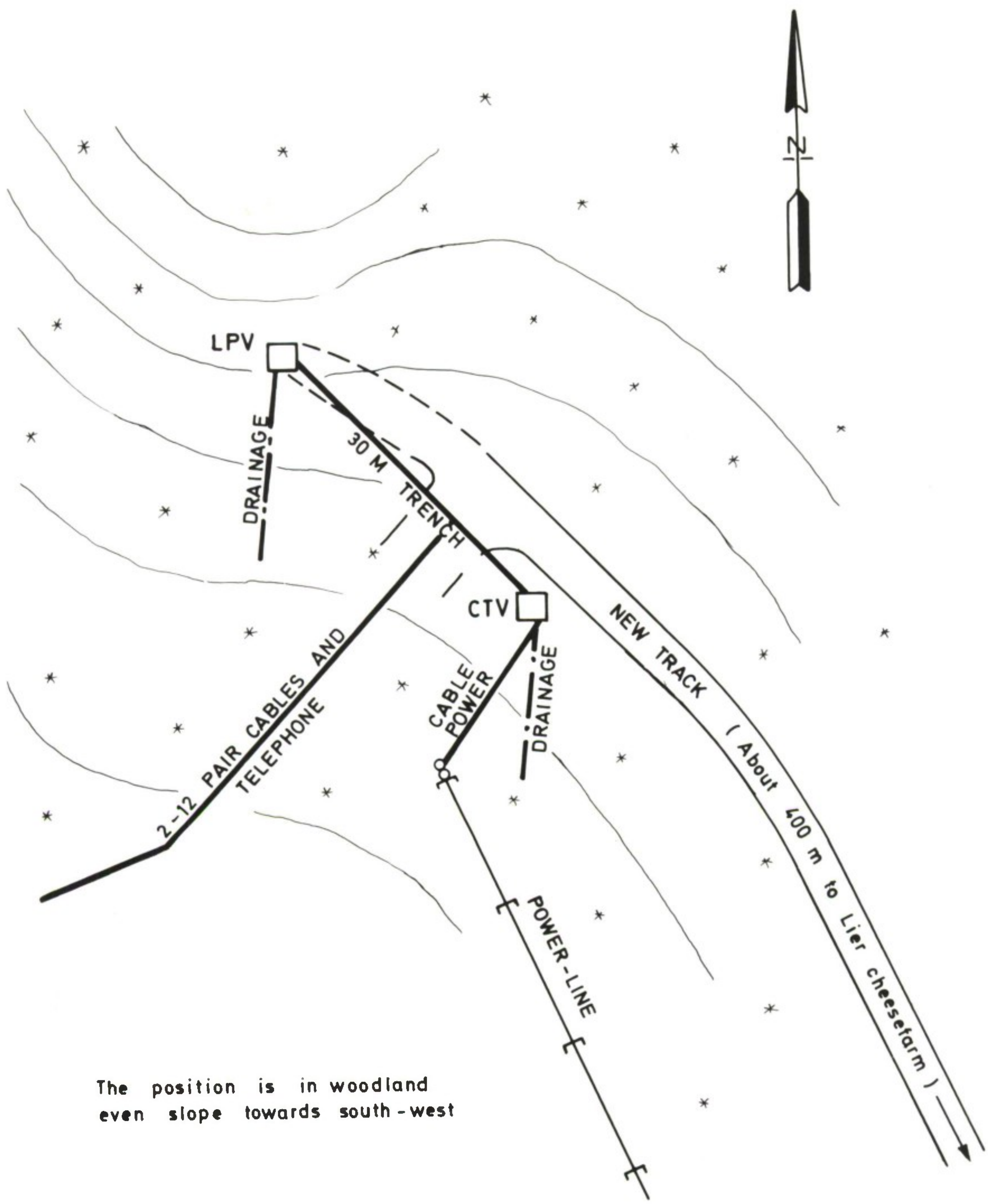


Figure 3.15 Central area, subarray 13C

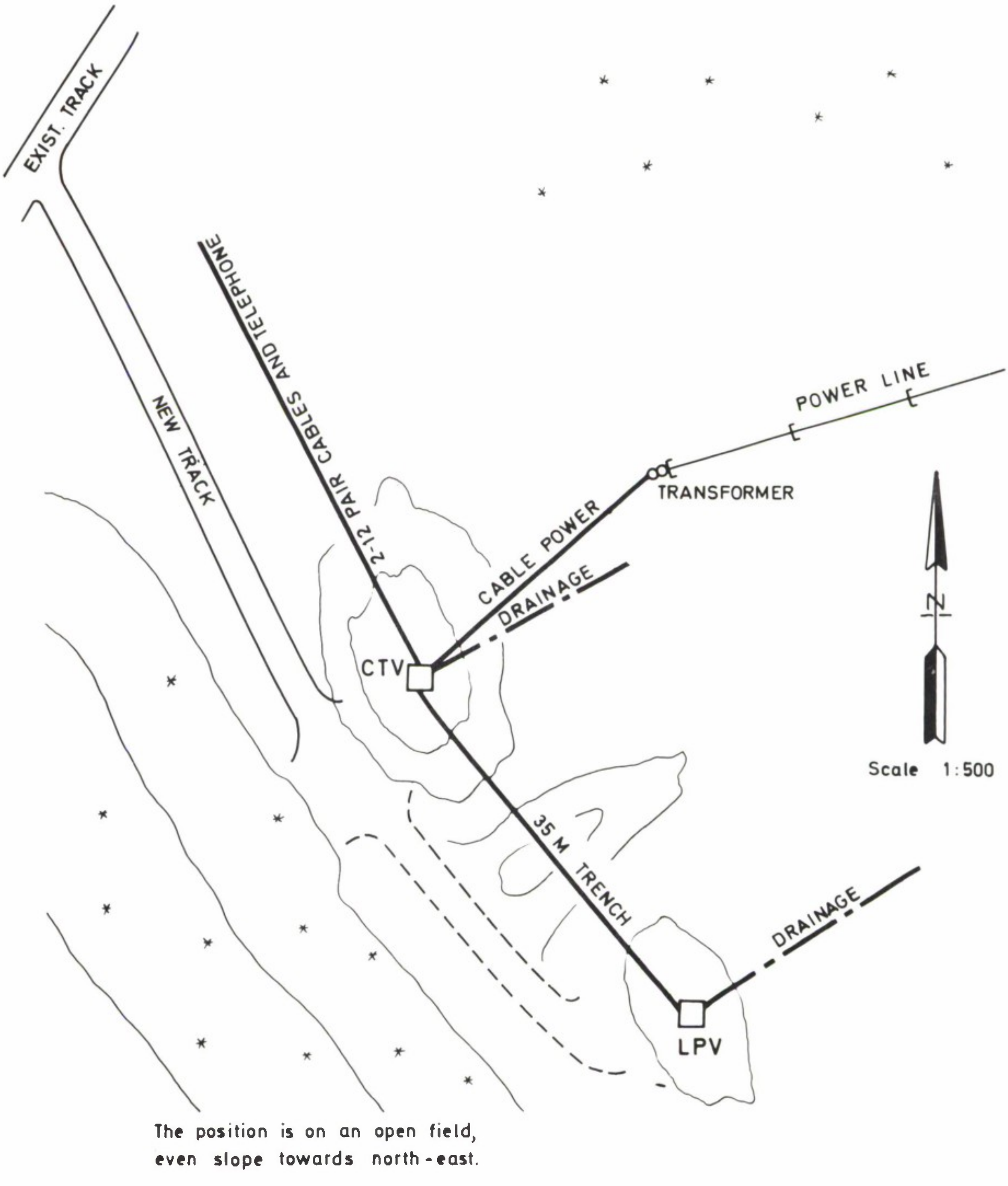


Figure 3.16 Central area, subarray 14C

NORSAR - PHASE 2 - 1969 PROGRAM

Long hole (through overburden) - construction report

Subarray no: 11C
Site no : 00
Drilling machine: Lindø/ Atlas BBE 51

Building inspector: Bergersen
Drilling inspector: K. Frog
Drilling diam. : 8"

Operation		Unit	Quantity	Remarks	Date	Sign.
Mounting					16-17/9	RD
Bedrock sounding		m	8.35		17/9	RD
Drilling	Overburden	m	5.35		18/9	KF
	Rock	m	3.0		19-22/9	KF
Casing	Diam.	cm	13.9		22/9	KF
	Length	m	8.35		22/9	KF
Injection	Length	m	3.0		23/9	KF
	Quantity	dm^3	60		23/9	KF
Welding position		m	6.0	From bottom	23/9	KF
Inclination	Position	m	6.5	From top	23/9	KF
	Angle	0^o	0^o 40'		22/9	KF
Pressure test		kg/cm^2	7.5		23/9	KF
Dismounting					23/9	KF
Excavation	WHV	m^3	6.3		24/9	KF
	Ditch	m	5.0	D=1.0m(2m)D=0.5m(3m)	24/9	KF
Construction of house					25/9	KF
Backfill					25/9	KF
Marking					25/9	KF
Cleaning of site					25/9	KF
Distance to water		m	260			KF
Final length casing		m	7.6		25/9	KF

Geology : Gneiss

Remarks :

Figure 3.17 Example of drilling report, C-ring

4 TRENCHING AND CABLELAYING

4.1 Preparations

When the seismic points had been fixed, the next step was staking of the cable routes. This job was left to the local forest intendant or agriculturist, who usually knew the terrain well and could suggest a reasonable route compromise based on parameters like trench length, number or type of cable, type of ground, forest quality, topography and landownership boundaries. It was, however, made clear that the trenching contractor was free to make small deviations from the proposed route if such deviation served to lower the total cost.

4.2 Subcontracting

Trenching and cablelaying for the 1968 program were carried out fairly late in the building season and were hampered by lack of cables. The trenching program for 1969 appeared to be easier, as trenching could start in late spring and 200 km cable was already in storage at the factory.

Since most of the trench routes were not staked until late spring, however, the tender documents for cable trenching were worked out while quantities were uncertain and the distribution of quantities in the various categories (rock, agricultural land, forests, etc) was unknown.

As in 1968, the contractors might also be wanted by the telegraph administration and local power companies to carry out trenching for telephone and power supply for the same installations, and in special cases contractors had been allowed to release men and machinery for these tasks.

The specifications of the tender documents informed the contractors of all these uncertainties. In spite of this, the prices offered were quite acceptable and sometimes even lower than in 1968. As for the rate of progress, it was obvious that time extension would have to be granted if the contractors were stopped or delayed by reasons beyond their control, such as lack of cables and troubles with landowners.

Tender documents were sent out in February 1969. It was known from experience in 1968 that small firms with limited capacity had to be avoided, but to exclude such firms proved difficult since there were few medium-size firms of the kind needed. Large firms with their large and highly paid administration would, on the other hand, tend to be too expensive.

After comparing tender prices and judging the capacity of the bidding firm, it was decided to share the trenching and cable-laying tasks between five different firms, with the 13 subarrays distributed among them in the ratio 7:2:2:1:1. One of the reasons for leaving more than half of the job to a single contractor, Hagen & Godager, was the very good service this firm had rendered in the 1968 program.

4.3 Implementation

As soon as the snow conditions permitted, final staking was carried out by the contractors and revised lists of landowners were prepared. The rate of progress of the trenching and cable-laying was in general satisfactory. However some minor delays occurred in arrays with many landowners or uncertain landownership boundaries.

Normally the trenches were 50 cm deep and the width, identical to the hoe width, was 25 cm. In several cases deeper trenches had to be dug, due to stipulations imposed by the telegraph administration, power companies, landowners, road and railway authorities or terrain feature considerations (river crossings etc). In other cases, e g when laying power cables in the trenches, the width had to be increased.

The length of rock trenches was in some arrays much larger than estimated from the 1968 experiences, in other arrays the soil was mixed with boulders of various sizes, sometimes making the progress almost as slow as for rock trenches. This was especially true for subarrays 08C and 07C. As the summer was quite dry, no special problems were met in swampy areas, and in most cases very little damage was done to cultivated land.

The backfilling was carried out shortly after the digging and presented no special problems. Backfilling had to be carried out with care to avoid damage to the cable, and the result was comparatively few cases of damage with resulting break or short-cut.

Before completion of the work the contractors had to set up markers with NORSAR signs and numbers, and work out a log book with all necessary information. The log books are written in Norwegian and are mainly of interest for the field maintenance group.

The cables laid in the trenches were telephone cables, various types of power cables and 6- and 12-pair seismic cables.

Telephone and power cables were ordered directly by the NTA and power companies, while the necessary quantities of 6- and 12-pair cables were ordered by NDRE in January 1970.

During the construction period there was some shortage of 12-pair cables, but after careful distribution of the available quantities no serious delay was noted.

The trenching and cable-laying task was completed by the end of September 1969. Table 4.1 presents a few data concerning the trenching and cable-laying.

4.4 Documentation

All subarrays were photographed from the air by the subcontractor Widerøes Flyveselskap A/S, who delivered complete photo-coverage on a scale of 1:15 000. Since only about 40% of the trenches (and less in the 1968 subarrays) were visible on

Array	02C	03C	04C	05C	06C	07C	08C
Contractor	Hagen & Godager	Hagen & Godager	Hagen & Godager	Hagen & Godager	Hagen & Godager	Hagen & Godager	Karsten Smedsrud
Work started	12 Jun	12 May	16 Jun	12 May	8 May	5 May	19 May
Work finished	20 Sep	10 Sep	6 Sep	30 Aug	4 Aug	4 Aug	10 Aug
Length of rock trenches	2.38 km	4.35 km	0.94 km	0.91 km	3.18 km	5.20 km	5.27 km
Length of 120 cm trenches	0 km	0 km	1.85 km	0.50 km	2.03 km	1.50 km	0.29 km
Total length of cables	37.9 km	44.9 km	41.8 km	25.7 km	32.2 km	52.6 km	33.7 km
Total length of trenches	24.7 km	26. 6 km	24.0 km	14.7 km	24.4 km	31.4 km	25.2 km

Array	09C	10C	11C	12C	13C	14C
Contractor	Knut Framstad	A/S Linje-bygg	A/S Linje-bygg	Hagen & Godager	Johan Linnerud	Johan Linnerud
Work started	5 May	12 May	30 Jun	7 Jul	23 Jun	5 May
Work finished	24 Sep	18 Sep	25 Sep	10 Oct	10 Oct	18 Aug
Length of rock trenches	2.69 km	0.62 km	0.71 km	0.99 km	0.04 km	2.38 km
Length of 120 cm trenches	3.16 km	7.63 km	1.64 km	2.18 km	0.98 km	1.06 km
Total length of cables	41.6 km	39.3 km	52.7 km	31.5 km	28.3 km	31.2 km
Total length of trenches	25.0 km	26.7 km	30.2 km	23.7 km	24.2 km	24.3 km

Table 4. 1 Data concerning trenching and cable-laying

Estimated trenching rates:

Rock: 40 m per day
employing 1 back-hoe with driver; and 1 - 2 men with tractor and compressor for blasting and laying of cable.

Moraine: 200 m per day
employing 1 back-hoe with driver; 1 - 2 men for cable laying.

Swamp: 300 m per day
employing 1 back-hoe with driver; and 1 - 2 men for cable laying.

1 day = 8.5 working hours.

NORSAR - PHASE 2

Subarray 01A

Index to aerial photographs, showing sheet numbers

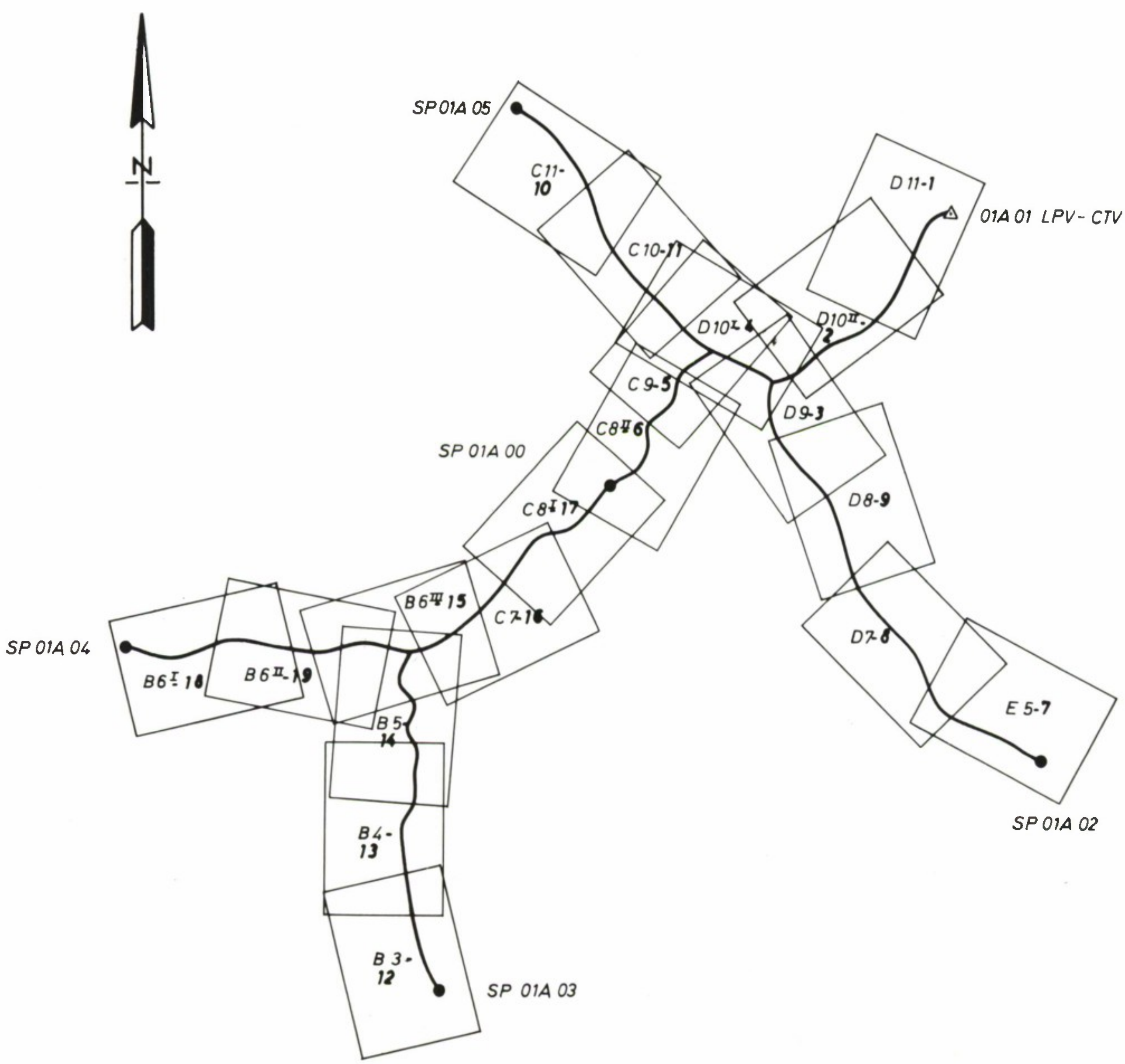


Figure 4.1 Example of subarray airphoto coverage

NORSAR - PHASE 2

Subarray 10 C

Landowner list

No.	Landowner	
1	Brandbu Almenning v/ bestyrer Ole Morset,	2762 Røykenvik
2	Andreas Haugen	2710 Bjoneroa
3	Knut Engelien	2890 Bruflat
4	Ingvald Vestland	2710 Bjoneroa
5	Ingvar Kleven	2710 "
6	Ovidie Kleven	2710 "
7	Lars Haug	2710 "
8	Sverre Sørum	2710 "
9	Ivar Kleven	2710 "
10	Torstein Bjerke Lie	2760 Brandbu
11	Johannes Sangnæs	2762 Røykenvik
12	Tordis Odnessveen v/ Stein Bjørgo	2713 Ringelia
13	Steffen Røken og A. Malkjern v/ Anders Malkjern	2710 Bjoneroa
14	John Strande	2710 Bjoneroa
15	Magne O. Egge	2762 Røykenvik
16	Ole Jan Røken	2762 "
17	E. Markestad og O. J. Røken v/ Ole Jan Røken	2762 Røykenvik
18	Gunder Næs	2762 Røykenvik
19	Jens Smedshammer	2762 "
20	Markus Melby	2760 Brandbu
21	Karl A. Mordt	2762 Røykenvik
22	Thora Hæhre	2712 Vestre Brandbu
23	Ole Toverud	2712 Vestre Brandbu
24	Ole Solberg	2760 Brandbu
25	Ringerike Skogforvaltning, Storgt. 11	3500 Hønefoss
26	Berven Skog v/ H. skogmester H.K. Gjerdrum	2752 Granvollen
27	Hans M. Røken	2762 Røykenvik
28	Anne Olimb	2725 Olum
29	Anders Nesbakken	2762 Røykenvik
30	Hans T.B. Koller	2762 "

Figure 4. 2 Example of landowner list

NORSAR - PHASE 2
Aerial photograph of part of subarray 01A
SHEET D11

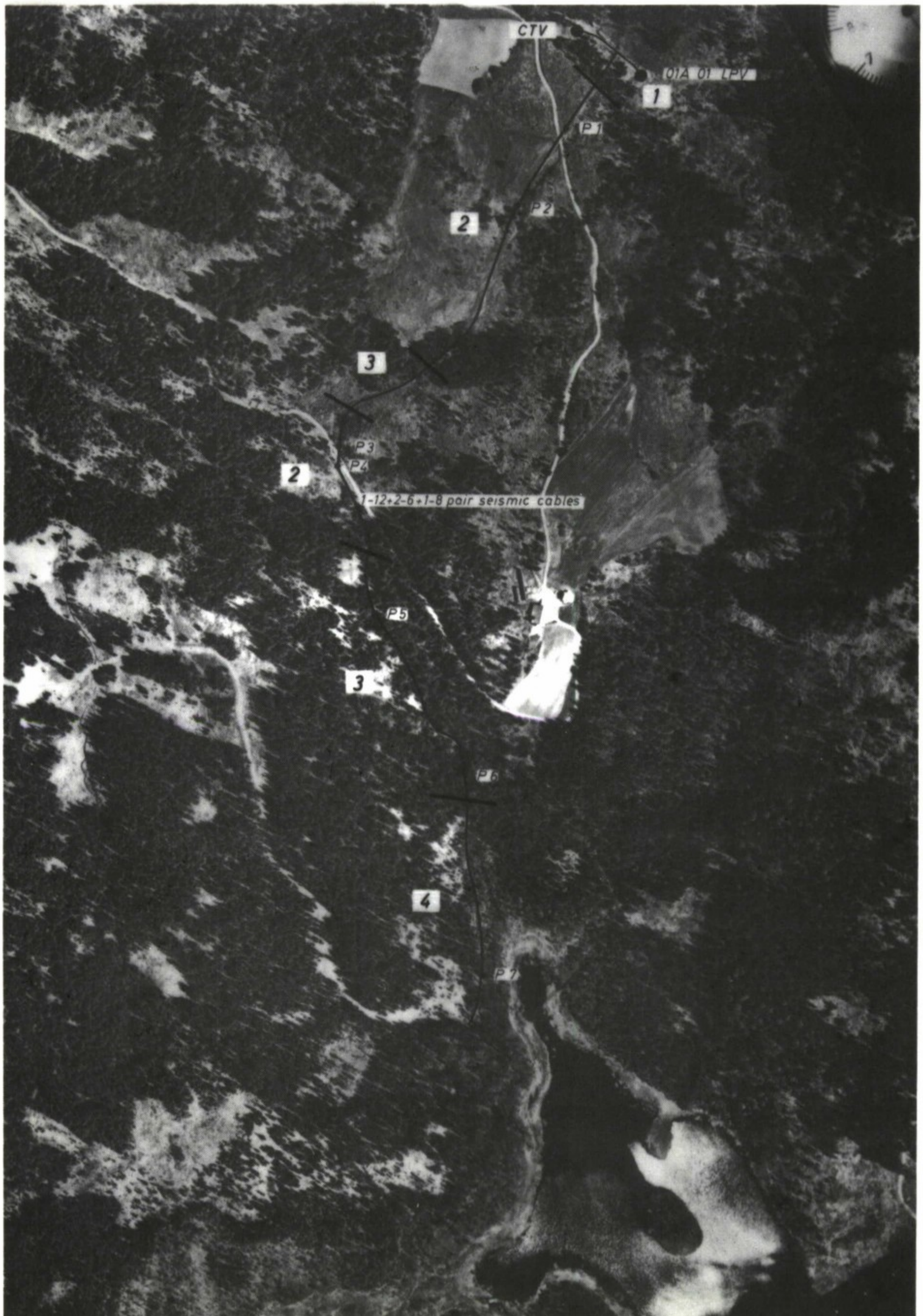


Figure 4.3 Example of airphoto 1 : 5000 with trenches and markers, vaults, land-owner boundaries and identification numbers

the air photographs, field personnel from the consultant had to plot on the maps the correct positions of SP-holes, vaults and trenches. The results were returned to Widerøe who then delivered complete maps on a scale of 1 : 5000 showing trenches, holes, vaults and markers. Based on log-books and information obtained locally, landowner names and boundaries were added, and the resulting material is contained in DOC II. Examples of the information found in this document are presented in Figures 4.1, 4.2 and 4.3.

5 POWER SUPPLY

5.1 General remarks

The layout used in the A- and B-ring power supplies was in principle maintained unchanged in the C-ring (see (2), 7), but the practical problems were on the average much larger. The main reason for this fact seems evident: The A- and B-subarrays were all placed in areas with low population density, but it is obvious that the C-ring generally covers even less densely populated territory. A simple consequence of this is longer distance on the average between the CTV and the nearest branch of the local commercial power system. Also, there is a correlation between low population density and terrain with low accessibility.

While the longest stretch in the A- and B-rings is a 3.5 km connection (02B), six of the C-ring power connections have lengths in the range 4 - 11 km.

5.2 Implementation

The first contracts with the potential suppliers of power to the C subarrays were established already in the fall 1968. As soon as the C-ring LPV/CTV sites had been located tentatively in January 1969, enquiries were sent to the local power companies, stating the subarray power requirements and asking for their advice as to type (pole line/earth cable, number of phases, voltage) and route of the connection. A rough cost estimate was also requested.

The power links were formally ordered in the first days of April 1969, and by the end of July most of the power supplies were completed, i e well ahead of the first installations in the vaults. At a couple of sites (02C, 07C) the power was in a week or two after start of installations; in these cases the instrumentation had to be accomplished by means of a mobile generator set.

In the majority of cases the power company itself was able to build the connection. Sometimes, mainly in cases of long lines, the power company had to subcontract all or part of the installation (02C, 07C, 09C).

All connections except 02C and 11C are pole-lines. At 02C the local authorities demanded that the connection should be trenched cable, the reason being that the area is much used recreation ground. At 11C it was practical to lay the power cable and telephone (data) cable in a common trench, for most of the distance together with a seismometer cable.

Table A1 in Appendix 1 presents the most important data of the power connections.

All CTVs have been equipped with emergency light. Appendix 5 presents the data for this arrangement.

6 TELECOMMUNICATIONS

6.1 Local connections subarray - NTA network

Connection of the C-ring CTVs with the NTA network was discussed in January 1969 and formally ordered at the end of the month. Final coordinates for the CTVs were transmitted to NTA in April 1969. In most cases the telephone cable was to be co-located with the seismic cable in a common trench over a substantial distance, and close cooperation in time and space with the trenching and cable-laying subcontractor was imperative.

Minor delays occurred in May due to lack of telephone cable, but in general the progress was satisfactory and did not hamper the overall work at the subarrays. In the fall the telephone cable splicing was delayed for a few weeks, NTA's capacity with respect to splicing seemed rather exhausted. By the middle of October 1969 all CTVs were connected and telephones installed except at 08C, 10C and 12C. The last one, 08C, was connected in December 1969.

The cable routes are drawn in Figures 2.2 through 2.14, and the local layout within the LPV/CTV areas in Figures 3.4 through 3.16.

6.2 Long distance connections subarrays - Kjeller DPC

The requirements stipulated for these connections are described in some detail in (2), p 64 and 65.

In the spring 1969 it had been evident for some time that the production in US of the Short and Long Period Electronic Modules (SLEMs) would be delayed, and that delivery would not be possible until spring/summer 1970. It was also clear that large parts of the NORSAR array would be available for some kind of on-line processing or registration of seismic events data from fall 1969. Being aware of this possibility, the Advanced Research Projects Agency (ARPA) had discussed various means of utilizing the potential. In May 1969 ARPA submitted to ESD/NDRE one of these ideas, the so-called "Plan D".

The consequences of Plan D for the communication requirements were in short: Exerting every effort, NTA should establish single-pair connections between Kjeller DPC and at least 18 subarrays as early as possible, i e some time in September or October 1969, when the local links were supposed to be ready. No quantitative criteria were specified for the quality of the channels beyond simple acceptance by the user, the IBM group.

NTA was informed about the plan and the number of pairs required for its implementation. NTA agreed to supply the communication channels wanted, taking excep-

tion only to the stretch Oslo - Lillestrøm, where available pairs were scarce. However, in late August 1969 it became clear that a carrier system Oslo - Lillestrøm would be installed during September, well within the schedule suggested.

Making the required number of connections operative proved to be a rather slow process, however. Many problems were encountered: scarcity of channels on some stretches, too high signal level which necessitated installation of attenuators, switching interference, and also a general lack of equipment and manpower within NTA. Simultaneous connection to 18 subarrays was achieved in December 1969. (See chapter 10 for details of the Plan D implementation.)

In principle all subarrays were physically connected to the DPC in the beginning of 1970, but generally the quality of the channels left much to be desired. In fact, few of them would at that time give acceptable error rates when using the selected modem, ITT type GH 2003 (see (2), p 66).

The problems were taken up with the NTA Board in meetings in January and February 1970. An important result of the discussions was an agreement to the effect that the CCITT recommendation M102 should serve as criterion for the standard of the channels. (The definitions of this criterion are given in Appendix 2). A schedule for the completion of the circuits was also outlined, anticipating provision of lines at a rate that corresponded with the delivery of SLEMs. According to this schedule the first line was to be ready by mid May 1970, and from then on two per week.

This program did not hold, however.

The first SLEMs were installed in the beginning of July 1970, and during the next two months one SLEM per week was installed on the average. At that time (end of August) the installation of SLEMs was discontinued because of an error located to the SLEM itself and due to a faulty design detail. Thus the acute need for new lines had passed for the time being, but it was obvious that the accumulated stock of acceptable channels was exhausted. One of the reasons for the circuit availability delay was late delivery of damping equalizers to NTA.

In a meeting at the end of August 1970, and at the specific request of NDRE, NTA consented to increase their efforts and also agreed to strengthen the line testing staff with personnel from Norconsult A/S (Teleplan), the NDRE consultants. The 31 October 1970 was accepted as the date when all 22 channels should have been brought up to the M102 standard. This schedule proved to hold and, because of time-consuming fault finding and reconditioning of the SLEMs, did not introduce any further delay in the overall completion of the array.

A brief summary of the most important control test results is found in Appendix 2. The data has been excerpted from a NTA test report: Innmåling av datasamband for NORSAR-prosjektet 1 september - 26 oktober 1970 (Control Measurements of the Data Communication Links for the NORSAR Project).

7 FIELD INSTRUMENTATION

Reference is made to (2), chapter 9, for a comprehensive description of the various systems in the field instrumentation.

The 1969/70 field technical installations may for convenience be broken into the following tasks:

- Installation of SP seismometers, installation in the CTV and LPV of commercial power, emergency no-break power supply, and otherwise all SP and LP circuits in front of the SLEM: by Siemens Norge A/S
- Check-out of the SP systems: by Teleplan A/S
- Installation and check-out of LP seismometers: by Teleplan A/S and the Noratom Maintenance (M) group
- Installation of modems: by the Noratom M group
- The SLEM integration: a Philco-Ford responsibility, in cooperation with the IBM group, the Noratom M group, with assistance from Teleplan A/S and under overall coordination by ESD

7.1 Installation of SP seismometers, commercial power, no-break power supply, and SP and LP circuits in CTV and LPV

A serious problem in connection with these installations was a pronounced lack of acceptable SP seismometers. The GFE-provided seismometers had previously been used in the LASA array. A planned reduction in the number of SP sensors in that array made a transfer to NORSAR possible. However, laboratory tests revealed that a very large percentage were unserviceable and had to be thoroughly reconditioned. The Noratom M group was responsible for the reconditioning, but owing to the fact that the Maintenance Center (MC) was still not fully equipped for the job at that time, this work was held up for a while.

Installation started week 28/1969 and, except for minor details, was completed by the end of October 1969, i e some two weeks later than scheduled (Figure 3.1).

7.2 Check-out of the SP systems

SP check-out started in the beginning of October 1969 and was not fully completed until the end of January 1970.

This was a sizable delay by comparison with the original program, but represented also a deliberate stretching of the schedule. It was agreed that there was no point in forcing the check-out, considering the big delay in the SLEM deliveries.

The check-out soon disclosed a shortcoming that was to take up much time and effort in the months to come: the natural period of the seismometer in the borehole was far outside specifications in a number of cases, even for reconditioned seismometers that had been adjusted at the MC immediately before installation in the field. Various explanations were put forward, and many means of overcoming the problem were tried without much success. It was finally determined that the reason for the changes in seismometer performance was the difference in temperature between

the MC, where the instrument is adjusted, and the field, where it must operate. The general trend was a marked increase in the natural frequency with decreasing temperatures. The test results from a special experiment conducted at the MC are presented in Appendix 3.

As a result of this, seismometers serviced at the MC have since generally been adjusted to about 0.95 Hz rather than 1 Hz, to compensate for the frequency change caused by the lower temperature in the borehole. Frequency change caused by mechanical dislocations during transport is also a problem, but better transport techniques have reduced it substantially.

Two visits by US advisers should be mentioned in this connection: Mr S N Heaps from the Geospace Corporation and Mr O D Starkey from Geotech (Teledyne). Their discussions with the NORSAR maintenance people were very valuable and a number of their recommendations have been implemented.

7.3 Installation and check-out of LP seismometers

This task was implemented in the period November 1969 - March 1970, except at subarrays 04C and 11C. The LPVs at these subarrays had been fitted to accommodate special LP seismometers (see section 10.2) and had to be reconditioned before ordinary LP seismometers could be installed. Such rearrangements were implemented in May/June 1970, followed by installation and check-out of the LP system.

Some faulty ITACHO amplifiers and LP seismometers gave rise to complaints and delays, but on the whole the LP equipment was no source of serious trouble.

Figures A4.1 through A4.8 in Appendix 4 show examples of the type of documentation produced during the check-out of LP as well as SP seismometers.

7.4 Installation of modems

The choice of modem and the testing of it is described in (2), p 66.

The modems were purchased through NTA and after control tests at the NTA workshops at Oslo and Lillestrøm were installed in the field and at the DPC during the period June - September 1970.

7.5 SLEM installation and check-out

The function of the SLEM in the data acquisition system has been described briefly in (2), 8.1.1.

These units are GFE and the stating of specifications, invitation of tenders for delivery, and procurement was an ESD responsibility.

The first batch of SLEMs was received in Norway in June 1970 and installation in the field, a Philco-Ford undertaking with assistance from the Noratom M group and from Teleplan A/S, started in July. Some 9 modules had been installed by the end

of August 1970 when the computer-assisted check-out disclosed unacceptable error rates (missing number) in certain operation modes. It proved to be difficult to pinpoint the origin of the fault, for a while it was not even possible to determine whether the computer or the SLEM was the cause. The malfunction was finally located to a shortcoming in one of the SLEM circuits. The circuit design was modified, and installation and final check-out was resumed in November. The SLEM integration was complete by mid January 1971.

7.6 Looping control system

Erroneous signals in the data stream may potentially be generated at various points in the data transmission system: in front of the CTV modem, in the CTV modem itself, on the telephone line from the CTV to the data processing center (DPC) in the DPC modem, or possibly in the data processing equipment, and cases could well be foreseen in which the source of trouble could not readily be located. To ease the identification of the error source and thus be able to maintain fast corrective maintenance, it was decided to equip the system with a looping arrangement.

The duplex low speed supervisory channel of the modem is used by DPC for selection of the following four modes of line operation:

A loop - loop on line side of DPC modem
B loop - loop on line side of CTV modem
C loop - loop on data side of CTV modem
Normal data transmission

The B and C loop conditions can also be manually controlled at the CTV. If necessary a manual call signal can be given from the CTV on the low speed supervisory channel without disturbing the data transmission. This signal will be detected at the DPC and the identification of the CTV is displayed on a call display panel.

In due time appropriate action is then taken by the operator at the DPC to establish telephone communication over the exclusive data line.

For further details about the looping arrangement, reference is made to Technical Specifications for Loop Testing Hardware, a Norconsult paper dated 18 June 1969.

8 THE DATA PROCESSING CENTER (DPC)

Reference is made to (2), p 88.

8.1 Space requirements, DPC equipment

The most important of the data acquisition and processing equipment to be housed eventually at the DPC at Kjeller, consisted of the following:

22 Modems
2 IBM 360/40 computers with card read punches and line printers
1 Special Processing System (SPS)

1 Experimental Console and a number of magnetic tape units, disc storage drives, other input/output terminals, and facilities for filing of magnetic tape reel.

One IBM 360/40 computer with peripherals had been installed in the existing KCIN computer hall early August 1968. This was a strictly temporary measure, however; no additions to the hardware could be realized unless much more space was made available on a more permanent basis.

8.2 Space requirements, DPC personnel

The first members of the DPC staff were hired by KCIN, the NDRE subcontractor for installation and operation of the DPC facilities, in July/August 1968, i e at the same time as the first IBM 360/40 was installed. To begin with, this personnel had to be accommodated in the old KCIN building.

At full strength the NORSAR staff would consist of 34 members, composing the following groups:

Project administration
Seismic Research
DPC Operations

The responsibility for operation of the NORSAR facilities was transferred from NDRE to Norges Teknisk-Naturvitenskapelige Forskningsråd (NTNF: The Royal Norwegian Council for Scientific and Industrial Research) on 1 July 1970. By March 1971 the DPC staff was as follows:

Administration

1 Project Manager (position open)
1 Administrative Assistant
1 Technical Assistant
3 Secretaries
1 Scientific Consultant (position open)

Research

1 Senior Seismologist
1 Mathematician (position open)
2 Programmers

Operations

1 Operations Manager
1 Operations Manager Assistant
1 Seismologist
1 Physicist
1 Senior Mathematician
3 Programmers
1 Computer Operator Supervisor
13 Computer Operators
1 Tape Librarian

i e altogether 34 persons

The above list does not include the personnel employed by IBM.

8.3 Rental and acquisition of housing facilities

The housing problems were discussed at length in meetings between representatives from ESD, NDRE and KCIN in the spring 1968. The fact that US Government funds could not be invested in real estate in Norway ruled out building of permanent housing facilities by means of contract money.

No suitable premises were to let in the area. A solution was eventually found whereby KCIN - using funds made available by the Institute for Atomic Energy (IFA), one of the KCIN shareholders - would erect a permanent building suitable for the NORSAR DP equipment and also containing a moderate amount of office space. These facilities, forming an extension to the existing KCIN building, would be let to the NORSAR project.

Construction of this building, designed by the IFA building department, started in the fall 1968 and was completed 20 June 1969. The first IBM 360/40 (8.1) was transferred to the new premises in the last days of June 1969. The second 360/40 computer together with the SPS and the Experimental Console arrived in Norway nearly a year later, and was installed in the new computer hall during the last days of June 1970. Figures 8.1 through 8.8 give a general view and show a few details of the facilities. Figure 8.9 is a functional diagram of the computer complex and 8.10 a floor plan of the computer hall. A few details of an emergency light arrangement for the computer hall are given in Appendix 5.

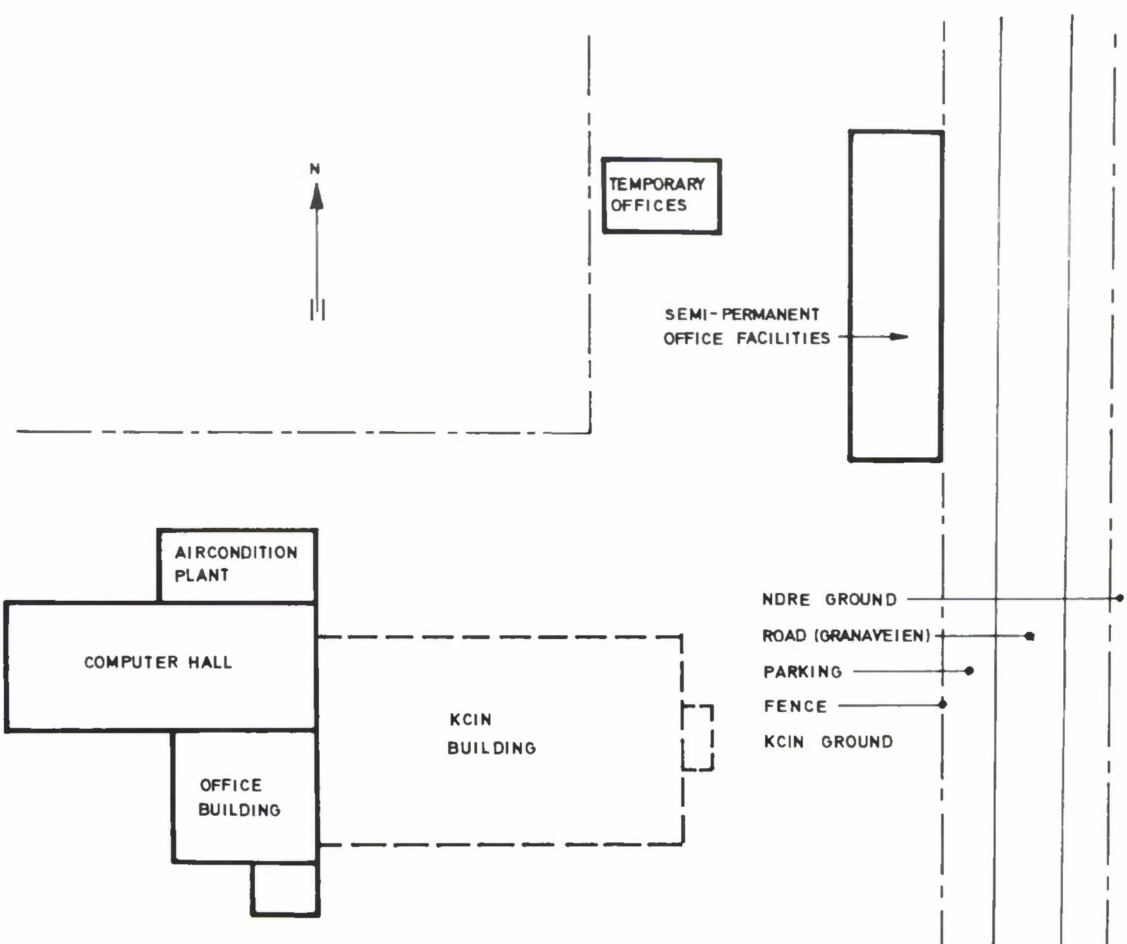


Figure 8.1 NORSAR DPC facilities on KCIN ground

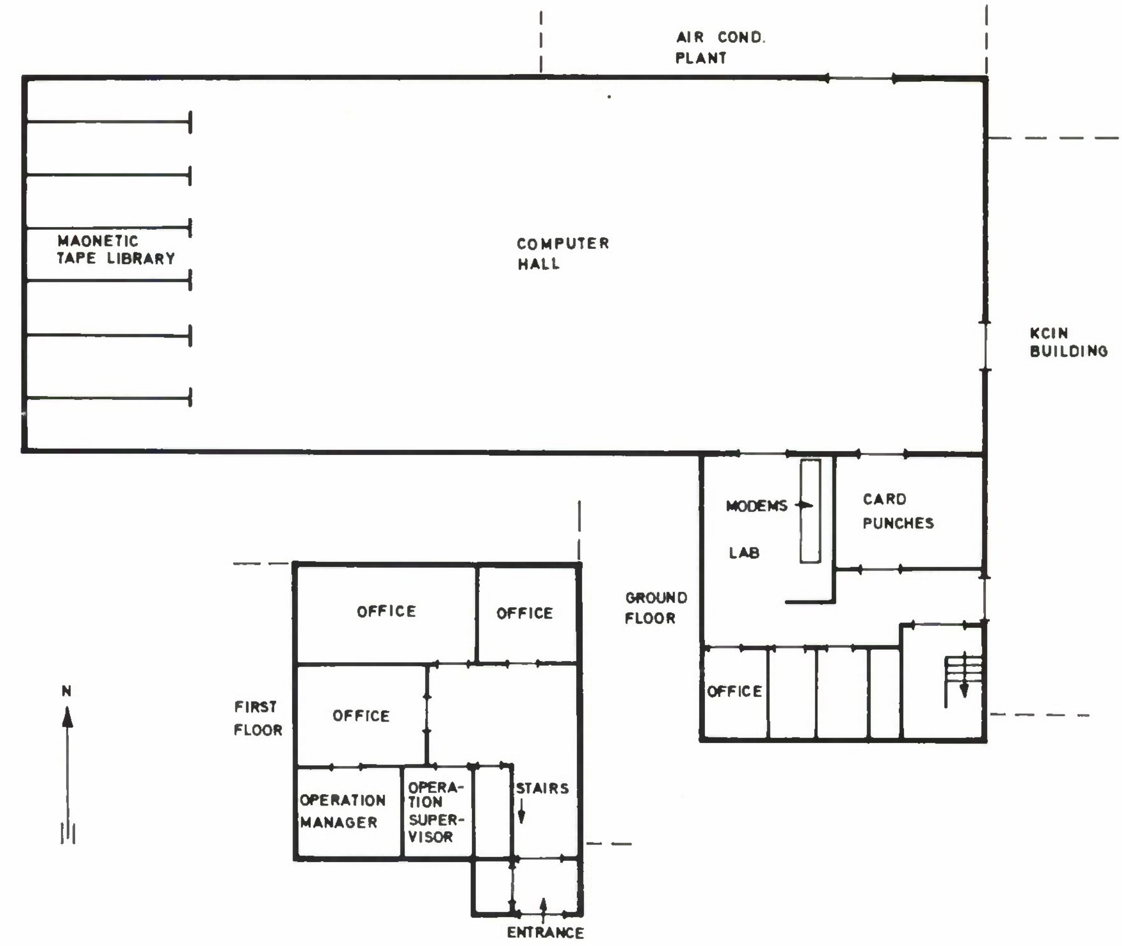


Figure 8.2 NORSAR permanent DPC building
(The proportions in this sketch are not correct; those of Figure 8. are.)

Figure 8.3 NORSAR permanent DPC building
(Left: computer hall, right: KCIN building)

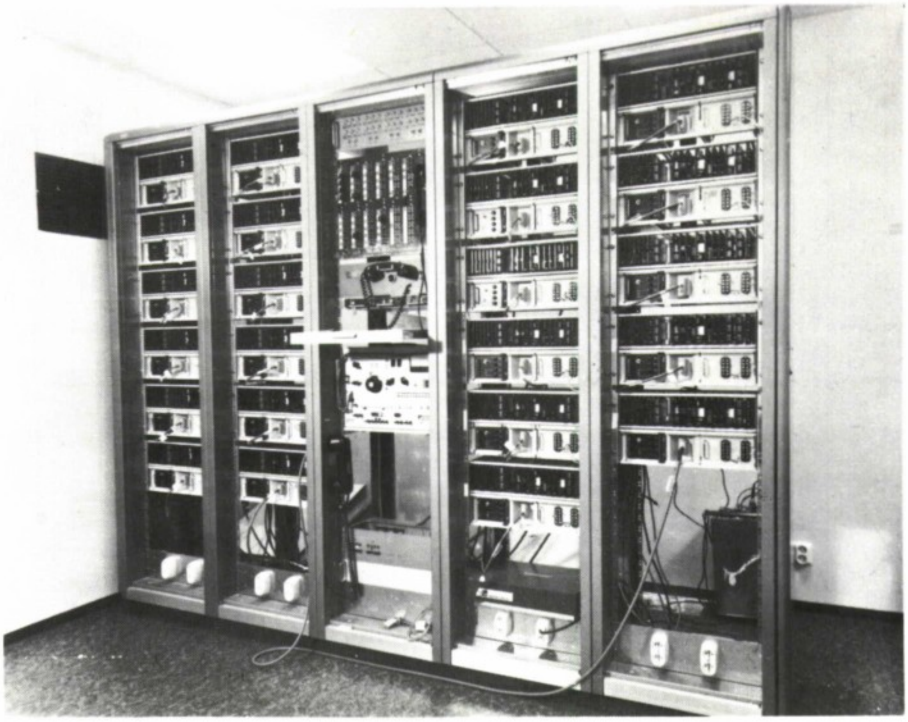


Figure 8.4 Modem cubicle, DPC
(Transatlantic link in the center)

Figure 8.5 Computer hall
(Magnetic tape reel shelves in the rear)

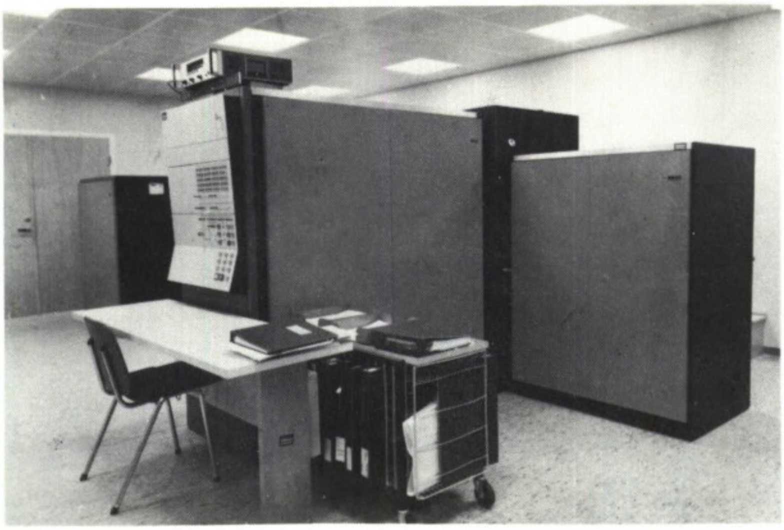


Figure 8.6 Special Processing System (SPS)

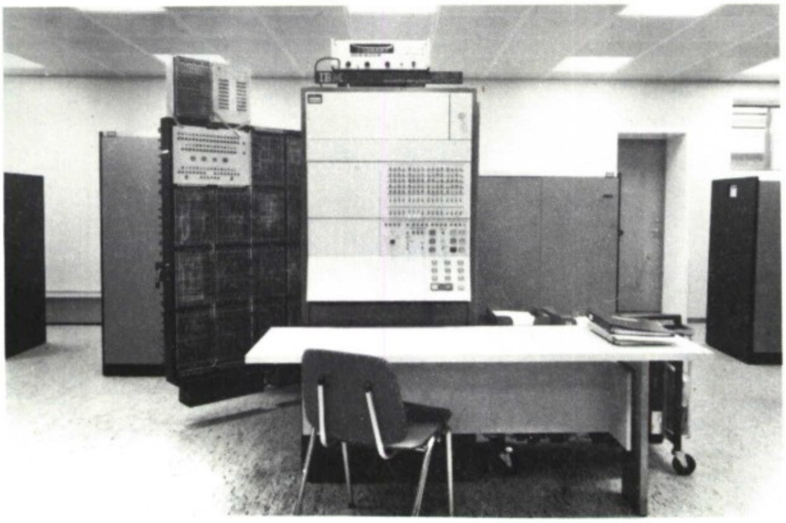


Figure 8.7 Front view of SPS

Figure 8.8 Experimental console

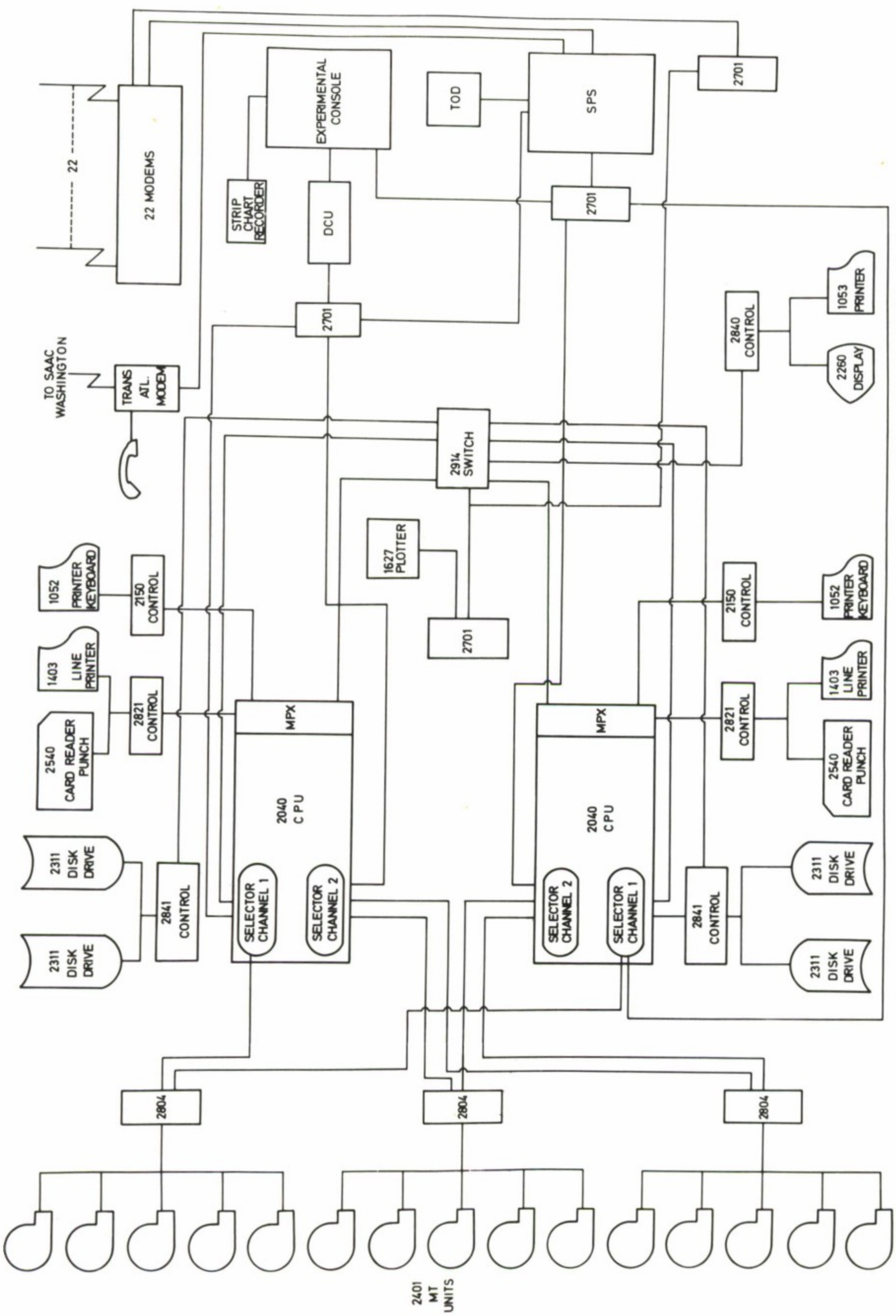


Figure 8.9 Functional diagram of the computer system

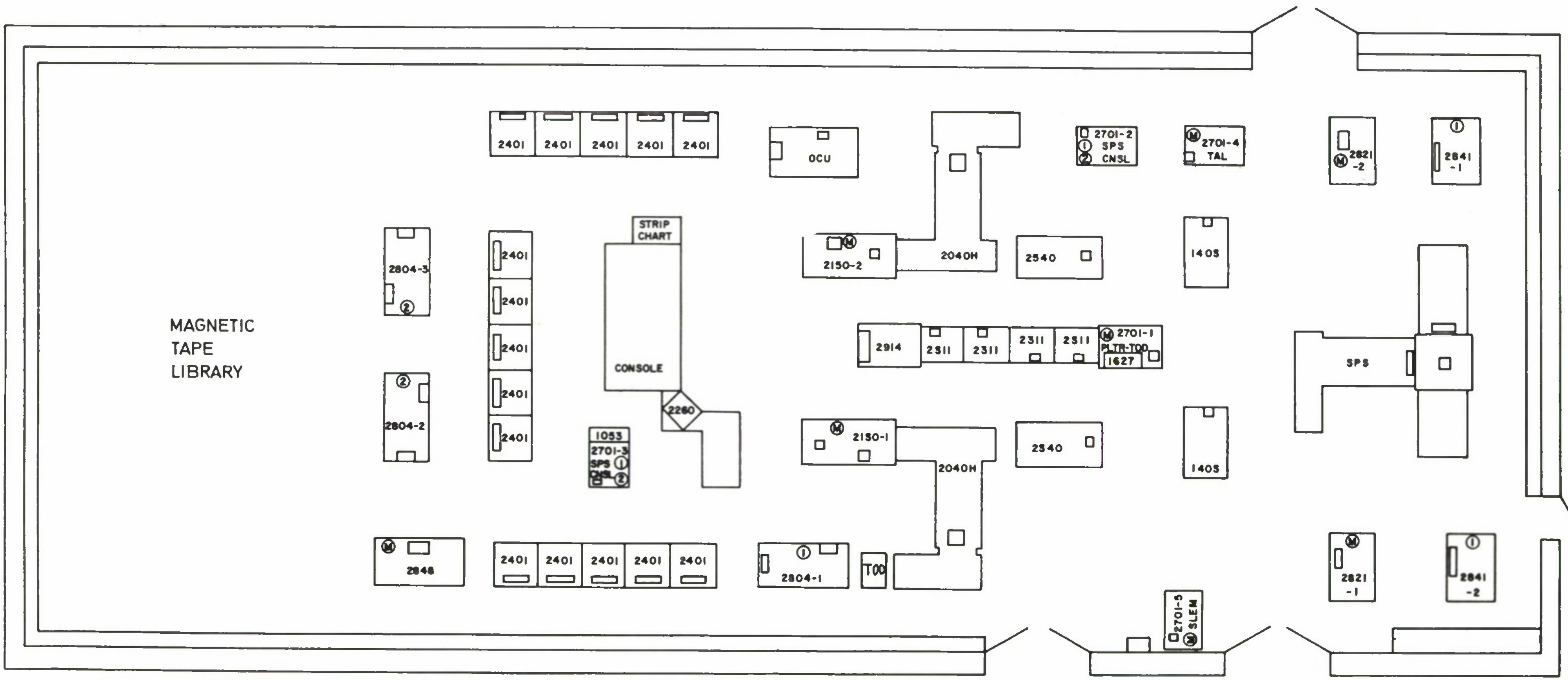


Figure 8.10 Floor plan, computer hall

Additional office facilities of a more temporary nature became available already in December 1968. This house (Figure 8.11) is constructed of prefabricated, semi-transportable units (make: Moelven Brug A/S). Three of the sections were added by NDRE in the spring 1970 for accommodation of ESD and NDRE project management staff, and another two units were added by NTNF in October/November 1970.

Figure 8.11 NORSAR semi-permanent office facilities

Another semi-permanent building, housing 6 - 8 persons, was placed at the disposal of NORSAR in spring 1969. This provides room for part of the IBM staff.

9 THE MAINTENANCE CENTER

Localization of the main base for the field maintenance crew was not a matter of course; there were favourable arguments both for placing it at Kjeller as well as somewhere near the geographical center of the array, e g in the Hamar/Brumunddal area. The final choice, Kjeller, had the benefit of allowing a much closer contact between the M group and the DPC staff. Certain tests of field equipment would also be much easier to perform at Kjeller.

Several possibilities for providing premises for the Maintenance Center were outlined by the M subcontractor, Noratom-Norconsult A/S, before a solution was found that could be accepted by ESD. It was finally decided that the necessary workshops and offices should be fitted up in a building that Noratom rented from IFA, on IFA ground some 500 meters from KCIN. In addition to this, the Phase 1 huts at Øyer and Romedal (see (1), section 2.8) should be moved to Kjeller and be joined together to form part of the MC.

Figures 9.1 through 9.9 give a general view of the premises and details of the workshops.

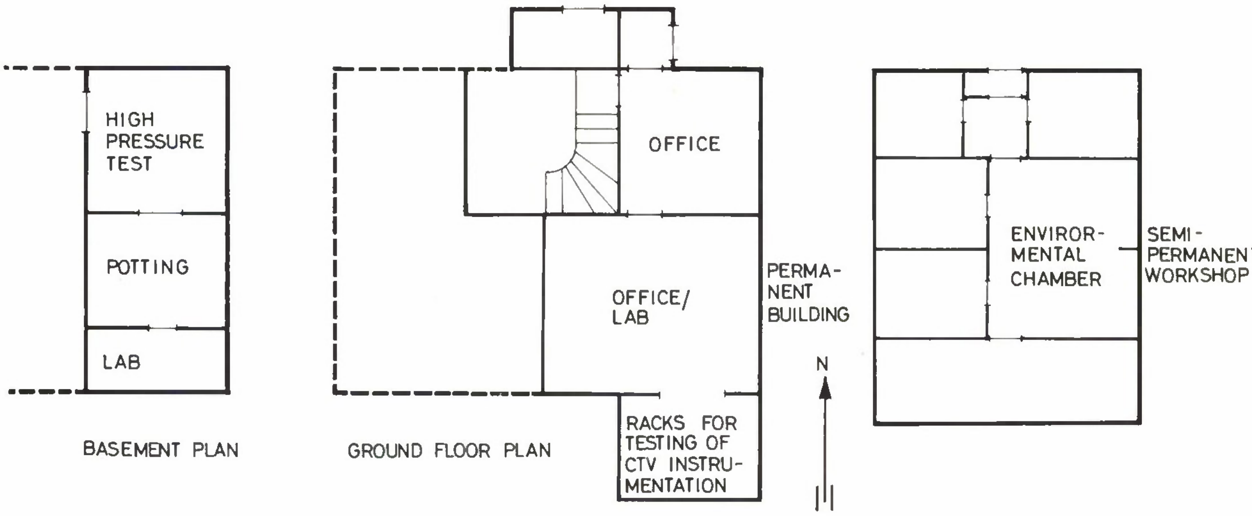


Figure 9.1 Maintenance Center (MC) in Noratom facilities at the Institute for Atomic Energy (IFA)

Figure 9.2 Noratom facilities at IFA

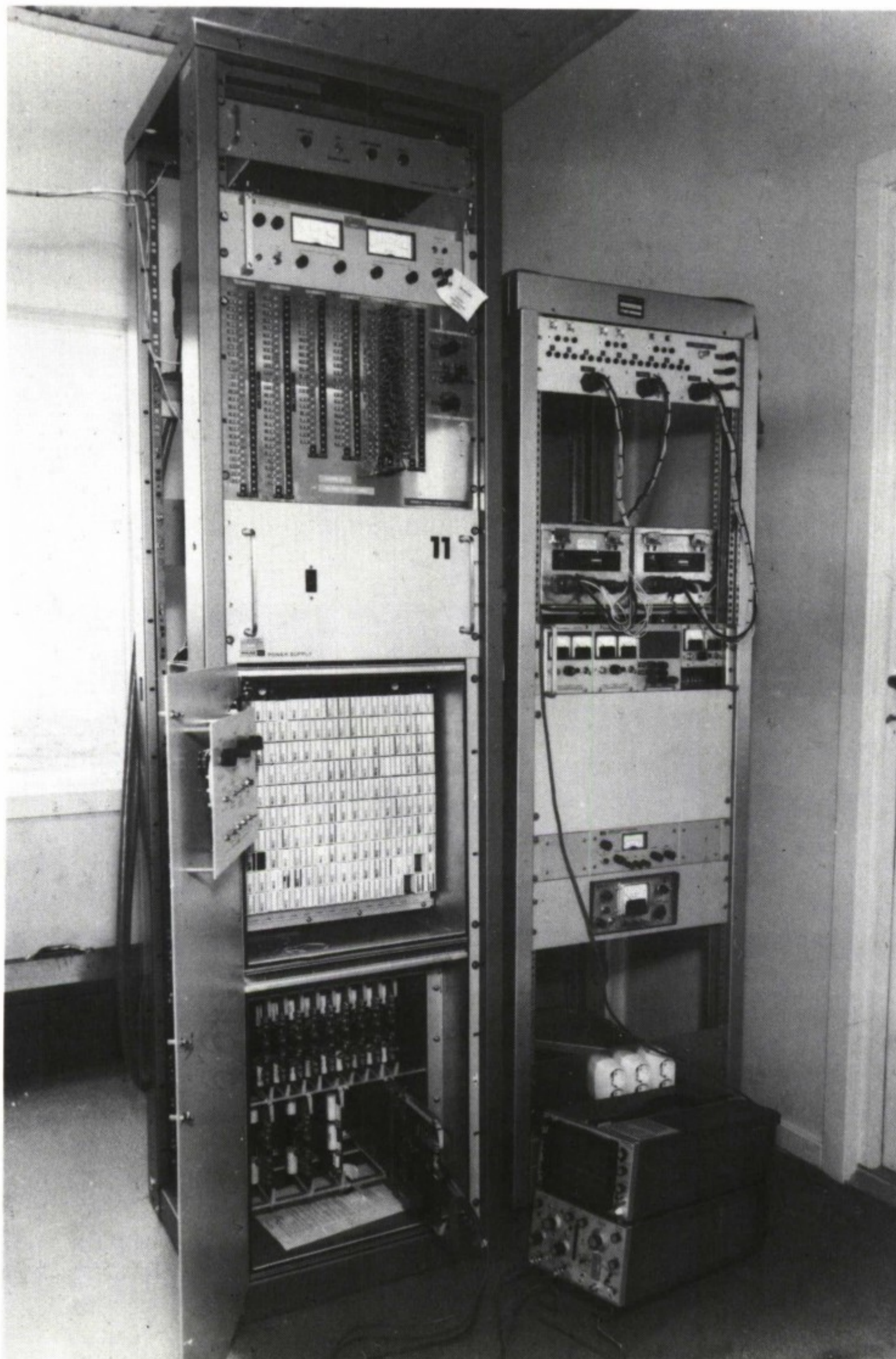


Figure 9.3 DS-rack with SLEM, and LP amplifier test rack in the Noratom workshop

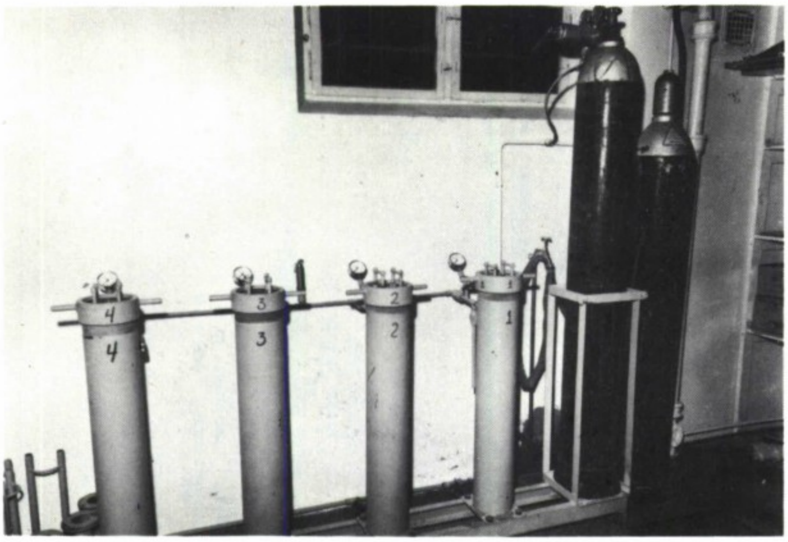


Figure 9.4

Equipment for high pressure testing of SP seismometers (Noratom workshop)

Figure 9.5

Bench used for potting of SP seismometers (Noratom workshop)

Figure 9.6

Extension of Noratom workshop
(Former huts at Øyer and Falldalen, Phase 1)

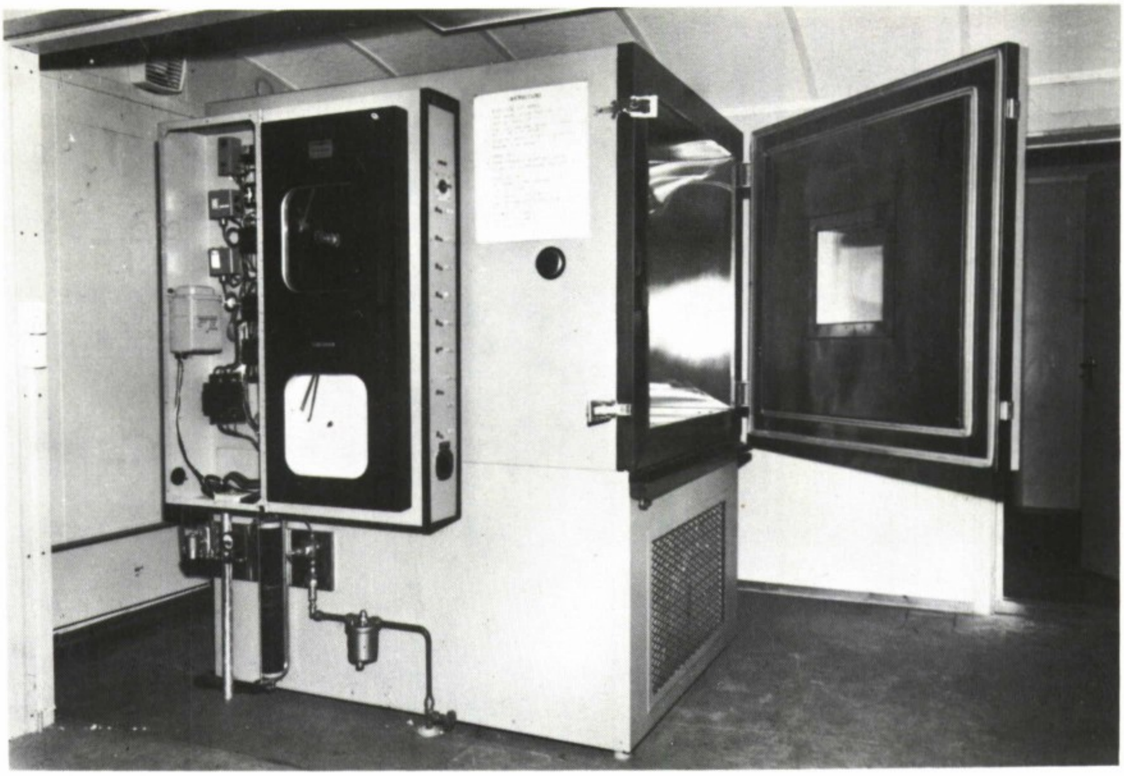


Figure 9.7 Environmental chamber for testing of field instruments

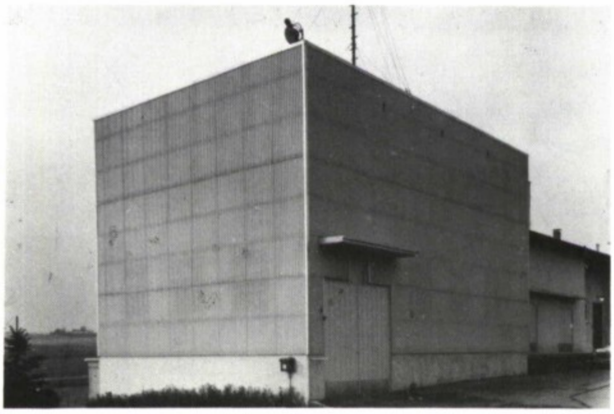


Figure 9.8 Main NORSAR store, on IFA premises

Figure 9.9 Main store, interior

10 OTHER TASKS

It is inevitable that a project of NORSAR's size and experimental nature will generate a large number of lesser problems and tasks, all of which cannot possibly be mentioned within the present report format. The major ones have been dealt with in chapters 2 through 9. Chapter 10 gives brief accounts of a few tasks that have called for appreciable efforts, but do not readily fall under the headings of the previous chapters.

10.1 Plan D

As mentioned in 6.2, various alternatives for utilizing the data-gathering potential of the NORSAR system prior to the SLEM integration were considered by ARPA in the spring 1969. The implementation of plan D, one of these alternatives, was proposed by ARPA and accepted by NDRE in May 1969.

The substance of plan D was as follows: The analog signals from one SP seismometer (i e the central one) in each subarray would be transmitted to Kjeller DPC by means of FM modulator/demodulator sets supplied as GFE from the US. The output from a maximum number of 18 demodulators (equivalent to signals from 18 subarrays) would be fed to a prototype SLEM available at the DPC, the digitized output from which would be processed there.

The aim was to obtain valuable data on wave velocities within the array area as early as possible. Plan D substituted a previous idea to the effect that the single available SLEM should be moved around from one subarray to another.

Responsible for the provision of long distance connections to the subarrays, NTA foresaw no problems except lack of telephone pairs between Oslo and Lillestrøm (Kjeller). Placing the SLEM plus recorders in Oslo was suggested as an intermediate solution until an Oslo - Lillestrøm carrier system was installed. However, it became clear in late August that the carrier system would be in during September 1969, and the plan could be realized as conceived originally.

Installation of the plan D equipment started in October, simultaneous connection to 18 subarrays was attained in December 1969. The experiment was conducted during the first half of 1970, and discontinued in May 1970, when preparations for the SLEM integration were initiated.

The data produced from the experiment have since been analysed, and the results fed back to the system in the form of spatial time and position corrections.

10.2 Long period high-gain experiment

At a meeting between representatives from ARPA, ESD and NDRE in the beginning of August 1969, and based upon a proposal from Dr Pomeroy, University of Michigan, it was decided that NDRE should have two or three LPV/CTV sites prepared for installation of special high-gain, very long period (XLP, 100 sec period) seismometers with accessories. These instruments had been developed by Dr Pomeroy and had produced data of such interest that further experiments elsewhere were considered appropriate.

Installation of this equipment at an LPV/CTV site would involve:

a) redesigning of the LP vault floor (flat, no LP steel tanks moulded into the floor) to accommodate the large XLP seismometer containers

b) provision of special racks and shelves in the CTV, to support galvanometers and photographic film recorders

c) trenching and mounting of extra cabling.

The plan, which led to an extensive planning effort on the part of NDRE and the consultant for instrumentation, was partly implemented: items a and c were realized at subarrays 04C and 11C.

In November 1969 NDRE was advised that the plan had been cancelled insofar as it involved NORSAR facilities. Additional work at 04C and 11C, to recondition the sites for the standard instrumentation, was ordered in March 1970 and had been completed by the end of April 1970.

Figure 10.1 is a drawing of the new LP tank arrangement in the 04C and 11C LPVs. This may be compared with the standard LPV configuration shown in (2), Figure 4.2.

10.3 Time of day synchronization

A WWV receiver was installed at KCIN in January 1969 to provide absolute time synchronization for the Time Code Generator at the DPC. A very high noise level locally prevented proper identification of the time signals, however, and an alternative source of absolute timing was a requisite.

A time laboratory belonging to the Norwegian Air Force Supply Command (LFK) and situated less than a mile from the NORSAR DPC provided a solution to the problem. The laboratory is equipped with a quality crystal oscillator and a high stability cæsium clock, the former being checked regularly by the latter.

LFK kindly agreed to make the necessary time signals available to NORSAR on a continuous basis, and the following set-up was established (Figure 10.2):

> 1 Hz, P.5 ms positive pulses (Tick Pulses) from the x-tal oscillator are converted to 1 Hz, 5 ms negative pulses at LFK and transmitted via a telephone line to the Time Code Generators (TCG) in the computer hall. The TCGs are not slaves of the LFK oscillator, however, and it is up to the DPC staff to control and adjust their synchronization by means of a special ON TIME control lamp and an ADVANCE/RETARD switch.
>
> Further control possibilities are provided by utilizing WWV signals received at LFK (low local noise level) and either used for checking the LFK x-tal oscillator or transmitted to NORSAR DPC. It is claimed that the x-tal oscillator is correct within one millisecond.

10.4 Suppression of 50 Hz noise occurring at certain SP channels

During the SP check-out performed by Teleplan A/S, the instrumentation consultant, it was discovered that rather strong 50 Hz noise penetrated into some of the analog signal channels; up to 6 V p-p was measured at the RA-5 amplifier output in some cases. The noisy channels were always found at sites where high-tension overhead power lines passed the area, and there was also a pronounced diurnal variation

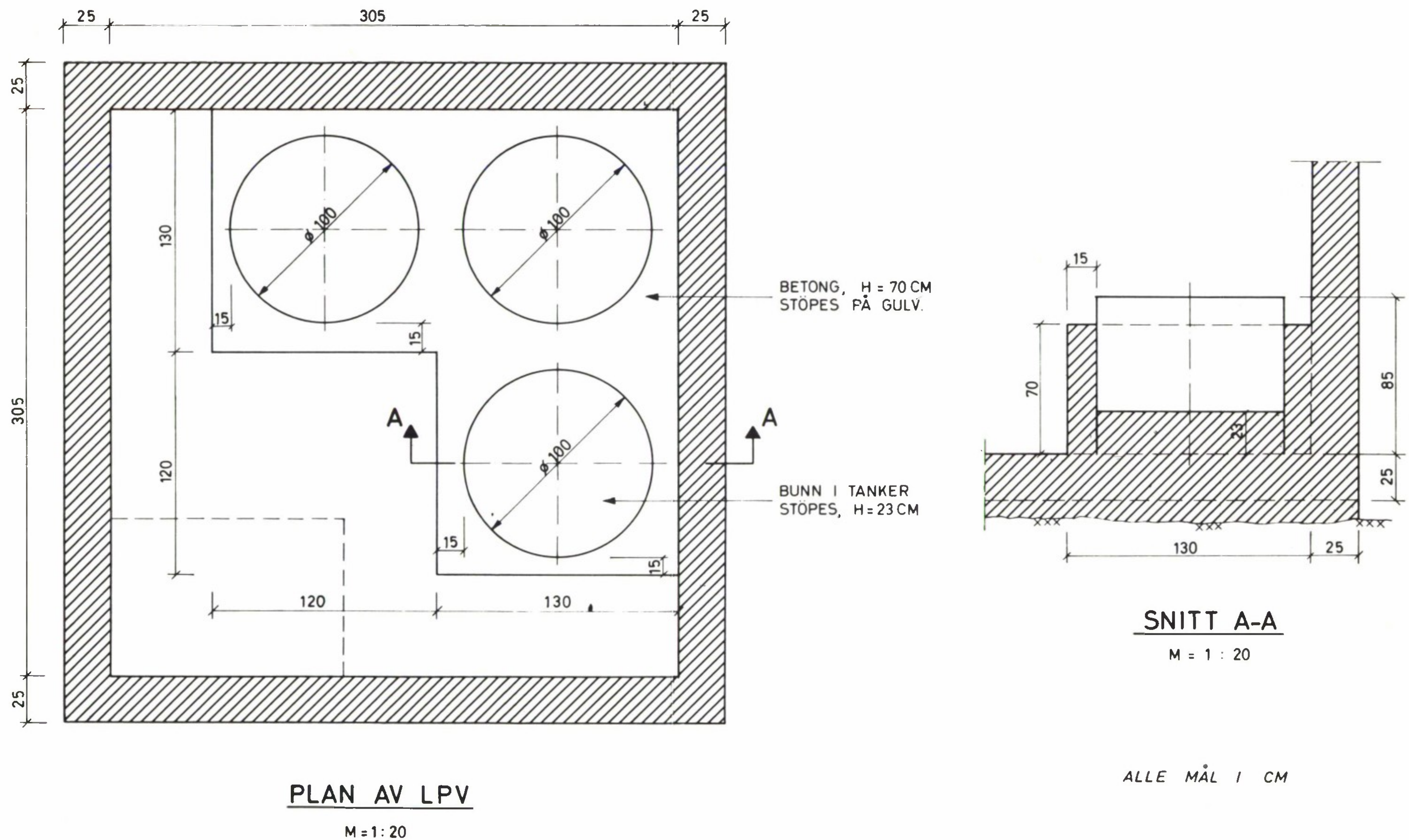


Figure 10.1 LP tank arrangement in the 04C and 11C LPVs

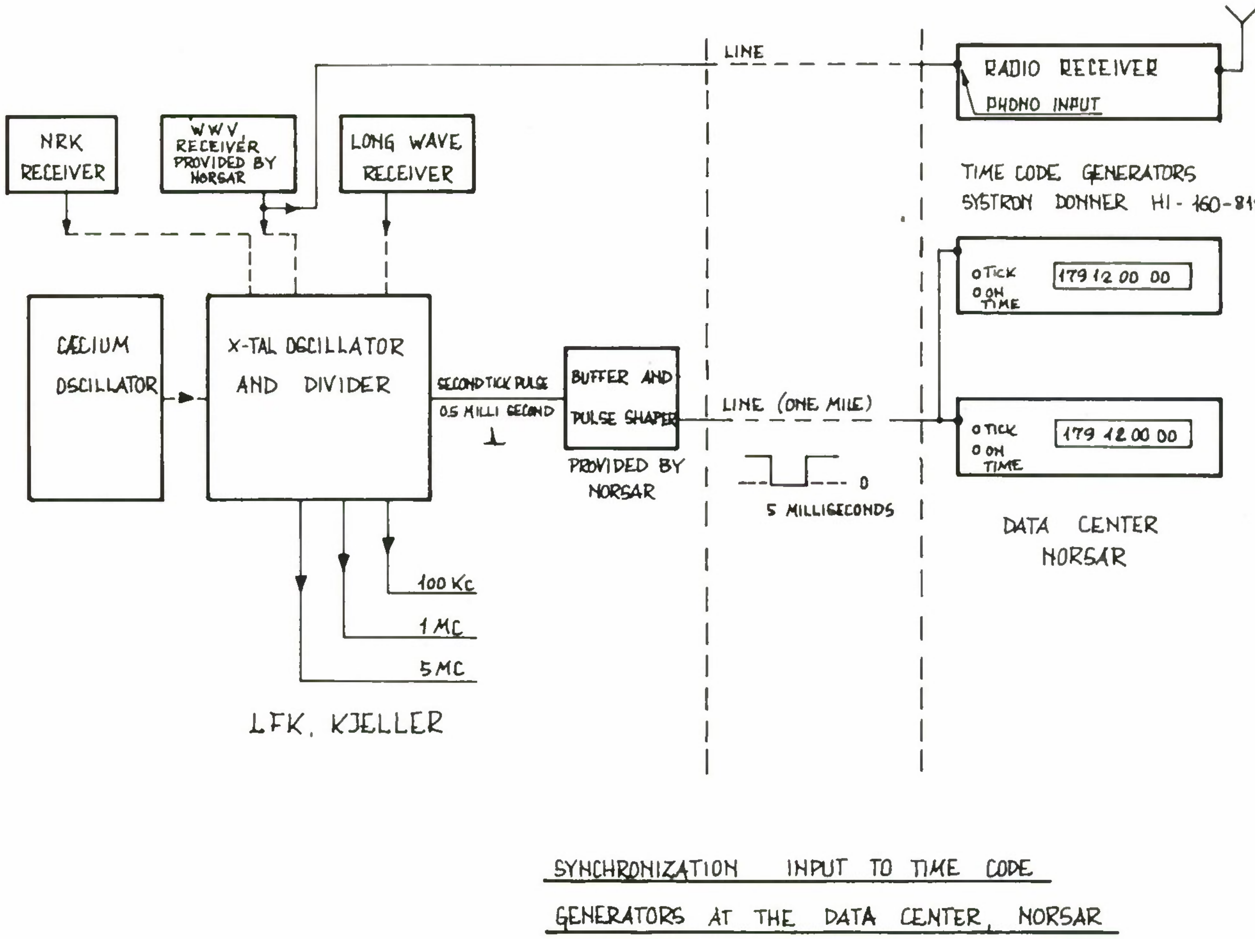


Figure 10.2 NORSAR DPC timing facilities

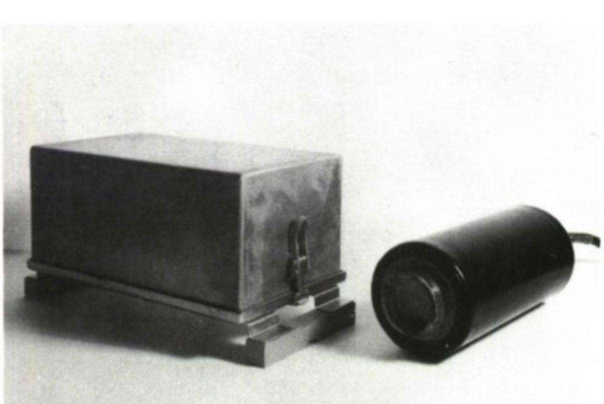


Figure 10.3 Insulation of junction box and SP seismometer

Figure 10.4 Insulation of the SP seismometer supporting rod

which obviously could be correlated with variation in the public power load. There was thus little doubt about the origin of the noise.

Even if 50 Hz noise is filtered out by the SLEM, there were weighty reasons (e g reduction in the RA-5 dynamic range, occurrence of modulated noise, saturation from noise, spikes) that called for means of suppressing the noise. The task was charged with Teleplan A/S.

The problem proved to be more difficult to solve than first anticipated. Various means were tried, e g removal of data-coil center-tap, introduction of special seismometer cable with separate shield for cal-coil leads and data coil leads, and shielding of input circuit to RA-5. Some improvement was indeed obtained, but the noise reduction was still insufficient at the worst sites.

A final attempt consisted in complete insulation of the seismometer and the amplifier box from the outer ground. The improvement was dramatic, virtually no 50 Hz noise was detectable at the RA-5 output after the modification had been carried out.

Figures 10.3 and 10.4 give an impression of how the necessary degree of insulation was obtained. The modification was implemented in the fall 1970 at the following sites:

01A	02, 03, 04, 05 and 11
04B	05
06B	00, 01 and 05
07B	02 and 03
09C	01 and 04
14C	02

11 CONCLUDING REMARKS

Early summer 1967, when the ARPA proposal for installation of a large seismic array in Norway was first discussed, vague ideas of a total building period of some one and a half or two years were hinted at. This rather optimistic view, which was based on the assumption that the experiences from Montana (installation of the LASA array) could be repeated more or less unchanged on Norwegian soil, soon gave way for more realistic ones in accordance with the topography, soil, land ownership conditions and resources of the local construction companies. When the layout of the array was finally settled in spring 1968, the overall planning was based on completion of the constructional tasks by the end of 1969. Less well defined, the date for finalization of instrumentation (including the DPC) was at that time expected to be some time during spring 1970.

The construction tasks were largely completed within the stipulated period. Except for reconditioning of the LP vaults at 04C and 11C (10.2), any construction going on in 1970 had to do with non-vital tasks and did not on any account hold up instrumentation.

The total seismic system was completed and final acceptance runs were initiated during the first quarter of 1971, about one year later than originally anticipated. Various difficulties in connection with delivery and installation of the SLEMs (7.5) probably must take the main responsibility for the delay, but also much of the DPC equipment was late in arriving (8.3).

The check-out of seismometers with associated circuitry, and preparation of long distance lines (NTA) were also much overdue compared to the schedule (6.2, 7.2). However, it should be borne in mind that in these cases the rate of progress could undoubtedly have been forced considerably if this had led to an earlier completion date of the total system. This was clearly not the case; stretching of these time schedules proved to have negligible effect on the overall progress.

References

(1) - Final Technical Report, NORSAR Phase 1, Intern rapport S-37, Norwegian Defence Research Establishment (1968)

(2) - Interim Technical Report, NORSAR Phase 2, Intern rapport S-45, Norwegian Defence Research establishment (1969)

APPENDIX 1

DATA CONCERNING THE COMMERCIAL POWER SUPPLIES

Subarray	Local power company	Length of line in km	Type of line	Voltage
02C	Moksa Kraftanlegg	4	Earth cable	1000
03C	Åmot komm El verk	1.1	Pole line	230
04C	Elverum El verk	6.5	" "	22 K
05C	Elverum El verk	0.3	" "	230
06C	Løten El verk	0.3	" "	230
07C	Solør Kraftlag	4.5	" "	17 K
08C	Hurdal komm El verk	1	" "	17 K
09C	Hadelands El verk	5	" "	1000
10C	Hadelands El verk	0.3	" "	230
11C	Vestoppland komm Kraftselskap	11	Earth cable	1000
12C	Vestoppland komm Kraftselskap	4	Pole line	1000
13C	Vestoppland komm Kraftselskap	0.3	" "	230
14C	Lillehammer El verk	0.4	" "	230

Table A1 Data concerning the subarray power supplies

APPENDIX 2

DATA CONCERNING THE LONG DISTANCE COMMUNICATION LINES

A2.1 Definition of the CCITT recommendation M102

Figure A2.1 is a graphical presentation of the damping and group delay limits vs frequency defined by CCITT recommendation M102.

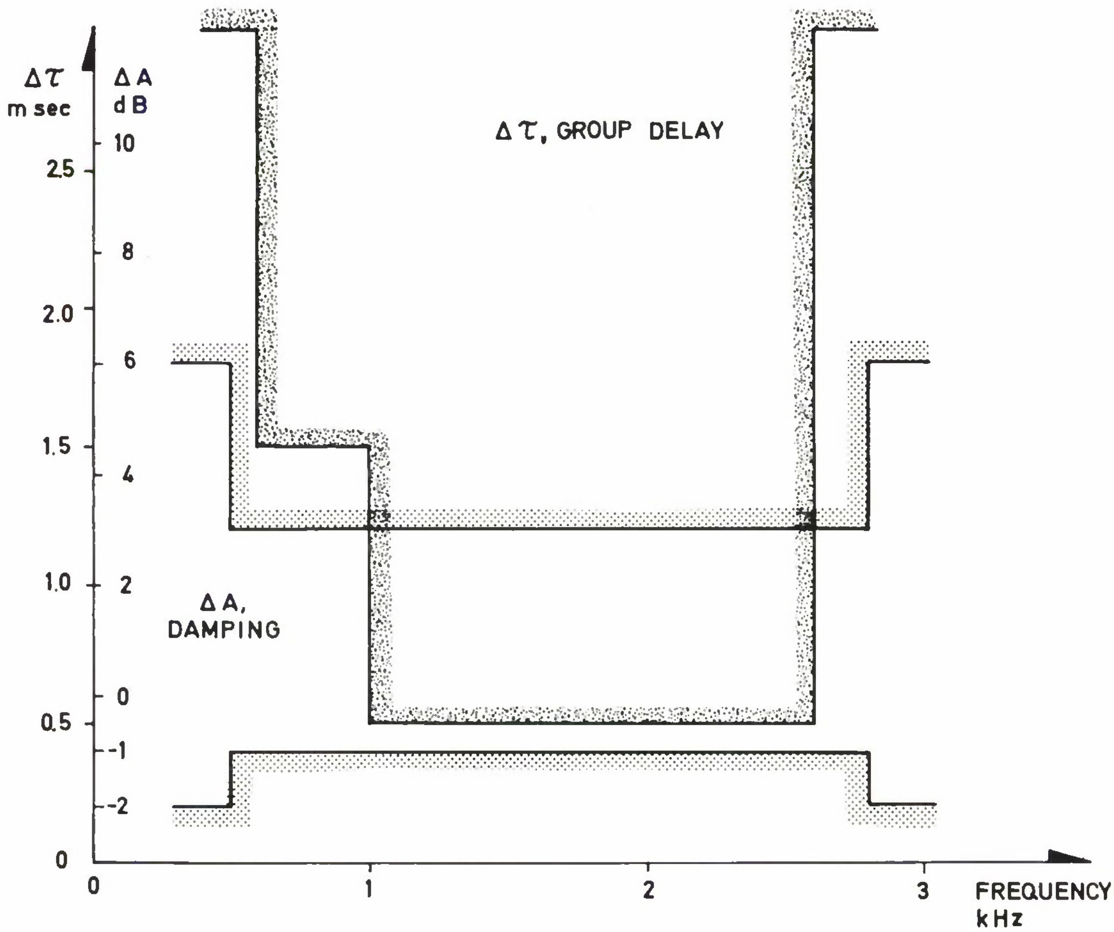


Figure A2.1 Damping and group delay limits defined for long distance telephone lines in CCITT recommendation M102

upper limit for group delay (ms)

upper
and
lower limit for damping (dB)

A2.2 NTA testing of the long distance lines

A2.2.1 Attenuation and group delay

Attenuation and group delay curves were recorded in both directions simultaneously over the frequency band approx 300 - 3400 Hz. X-Y-recorders connected to Wandel & Goltermann LD-2 measuring sets were used for the measurements.

All group delay curves satisfied the M102 criteria well. The great majority of the damping curves were also well within the limits; only for a few lines/directions did damping exceed the criterion slightly (high damping at the upper end of the frequency band). In all these cases the deviation was so marginal that further adjustment efforts were judged to be not worth while.

A2. 2. 2 Data transmission tests

Typical (and minimum) testing of each long distance line consisted of the following four runs, each lasting about 15 minutes:

a) Using a Datel test set and special test modems, 4000 blocks of each 511 bits (i e 2 044 000 bits) of pseudorandom signal were transmitted at 2400 baud rate in both directions simultaneously.

b) As for a, except for use of the ordinary CTV modem instead of a test modem.

c) As for b, except that the 2400 baud signal on one of the data channels was replaced by 125 blocks of 511 bits pseudorandom 75 baud signal on the special supervisory channel on the modem.

d) As for c, but with directions reversed.

In 169 out of a total of 188 run directions no error bits were recorded. Among the 19 in which error bits were detected, worst case was 79 error bits recorded in a single burst, corresponding to an error bit rate of 33.6×10^{-6}.

Most of the error bits per run direction were in fact recorded in a single burst. It is probable that the majority of the error recordings were due to on/off switching of equipment connected to the same mains circuit as the Datel tester. It has later been proved that the instrument is very sensitive to this type of mains noise.

APPENDIX 3

TEMPERATURE DEPENDENCE OF THE SP SEISMOMETERS

Table A3. 1 and Figure A3. 1 present the results of measurements of the natural frequency vs temperature for a number of HS-10-1 (ARPA) SP seismometers. The measurements were made by the M group at the MC, Kjeller.

Ser No	USP No	After several days in room temp ~ +20 °C	Natural frequency			
			After 3 days in LPV 04B +3.5 °C	After 24 hours outside Maint C ~ -20 °C	Variation from +20 °C to +3.5 °C	Variation from +20 °C to -20 °C
505	0368	1.05	1.30	1.56	+0.25	+0.51
374	0413	1.01	1.24	1.50	+0.23	+0.49
303	0396	1.09	1.18	1.30	+0.09	+0.21
489	0436	1.01	1.08	1.33	+0.07	+0.32
137	0431	1.09	1.15	0.91	+0.07	-0.18
347	0442	0.99	0.95	0.99	-0.04	—
				15 °C		
240	0398	0.93	1.27	1.35	+0.34	+0.42
207	0466	0.95	1.20	1.32	+0.25	+0.37
465	0415	0.96	1.20	1.29	+0.24	+0.33
221	0143	0.97	1.14	1.20	+0.17	+0.23
329	0433	0.94	1.10	1.22	+0.16	+0.28
579	0429	0.95	1.11	1.14	+0.16	+0.19
225	0424	0.94	1.07	1.20	+0.13	+0.26
388	0469	0.91	0.95	1.07	+0.04	+0.16
229	0461	1.01	1.01	1.18	—	+0.17

Table A3.1 Natural frequency of HS-10-1 (ARPA) SP seismometers as a function of the environmental temperature

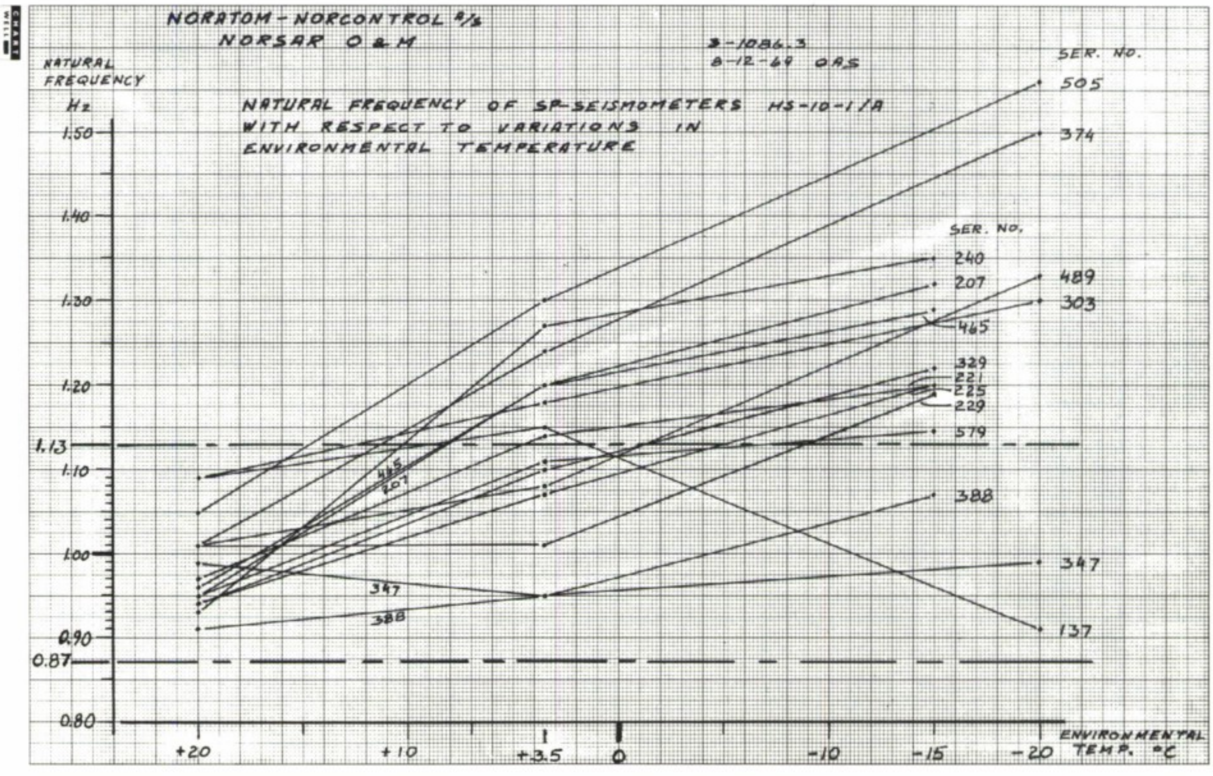


Figure A3.1 Natural frequency vs temperature for HS-10-1 (ARPA) SP seismometers
(Note that the temperature scale is reversed compared to normal practice.)

APPENDIX 4

DOCUMENTATION OF CHECK-OUT DATA FROM SP AND LP SEISMOMETER CALIBRATIONS

Figures A4.1 through A4.8 give a complete example set of the SP and LP check-out data presented in DOC IV, part 2.

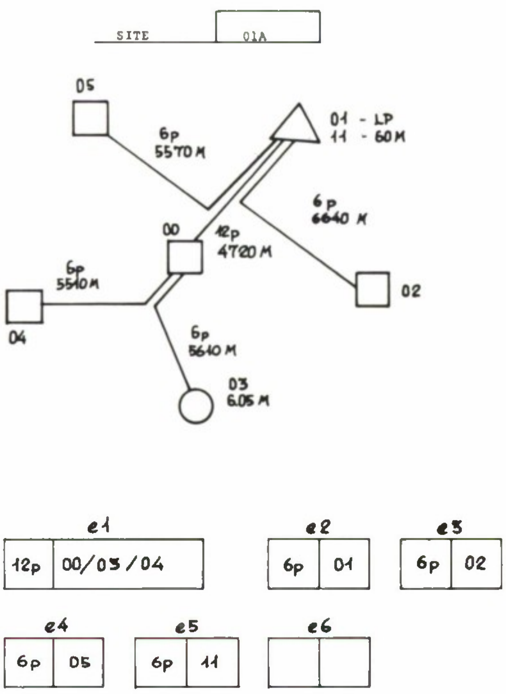


Figure A4.1 Layout of the subarray cable configuration and the cable termination in the CTV TS cubicle

SENSOR 01A00
CHECKED DATE 21.4.69
REPLACED
RECHECKED DATE

	Ser. No.	Gov. prop. No.
SEIS	437	0394
JA	8	0957
RA6	691	0539
~~JB~~/JC	1	0975

TS-TERMINATION
GAS-FILLED PROTECTION e 1
ZENER CARD ba 1

DATA OUTPUT TERMINALS + 3A
− 4A

RESISTANCES

	CABLE LOOP	CIRCUIT LOOP	INSULATION
DATA	244 Ω	44500 Ω	100 MΩ
EM CAL	245 "	260 "	∞ "
CAL AMP	252 "	1620 "	∞ "
POWER	122 "	"	∞ "
TELEPH	244 "	"	∞ "

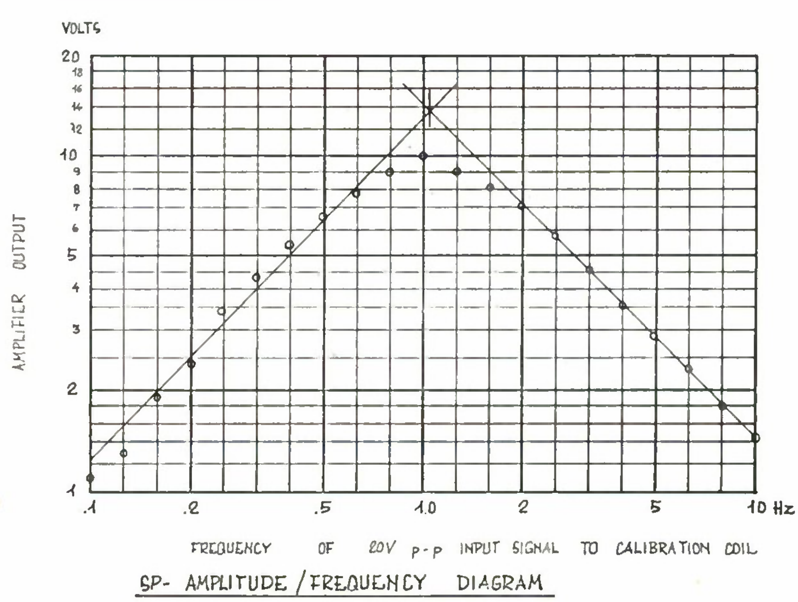
POWER DRAIN 23.5 mA
MINUS LEAD RESISTOR — Ω

NATURAL FREQUENCY 1.05 Hz

RA-5 ANPLIFICATION 10.5 V at 1 Hz, 20 V cal input
" 3 dB DOWN AT 0.115/230 Hz
" NOISE LEVEL 500 mV
" COMMON MODE 0.9 V at 50 Hz, 1 V input
" OFFSET, + TERM 9.68 V
" OFFSET, − TERM 9.92 V

SYSTEM RESPONSE 10 V at 1 Hz, 20 V cal input
" NOISE LEVEL 400 mV
" DAMPING 0.69 λ
" BREAK FREQ 1.03 Hz

Figure A4.2 SP check-out data



SENSOR 01A00
RECORDED DATE 23.4.69

Figure A4.3 SP amplitude vs frequency

DATA SHEET DATE 12.02.70 SITE OIA

		VERTICAL	N - S	E - W
Seismometer serial no.		118	237	236
MP Adj. Device " "			253	370
Period Adj. Device " "		269	275	270
Amplifier " "		6492	6491	6495
Additional glass spacers.	End			
	Right			2 x 3mm
	Left			
Gm, (V/M/Sec)		775	867	753
Gc, (Newtons/Amp.)		0,0320	0,0306	0,0302
Damping Resistance, Rd (Ω)		2420	2940	2400
Seismometer Coil Resistance	Data (kΩ)	46,2	46,7	47
	Damp (Ω)	542	533	536
Amplifier Gain (db)	T = 20 sec	67,9	67,9	67,8
	T = 25 sec	72,4	72,4	72,4
	T = 68 sec	79,9	80,0	79,9
Amplifier Dc Offset (mv)		+295	+75	+245
Blocked mass noice level at Amplifier output (mv)		≈ 5	≈ 5	≈ 5
Seismometer - tank time constant (hours)		≈ 4	> 3	> 8
LPV time constant (hours)		> 1		

Figure A4.4 LP check-out data

FREQ RESPONSE CALCULATION SHEET DATE 12.02.70 SITE 01A

PERIOD T (sec)	VERTICAL		N - S		E - W	
	Amplitude A (mv)	Sensitivity S (mv/μm)	Amplitude A (mv)	Sensitivity S (mv/μm)	Amplitude A (mv)	Sensitivity S (mv/μm)
8	$0.12 \cdot 10^3$	59	$0.15 \cdot 10^3$	74	$0.13 \cdot 10^3$	64
12	$0.80 \cdot 10^3$	175	$1.05 \cdot 10^3$	229	$0.90 \cdot 10^3$	196
15	$2.20 \cdot 10^3$	307	$2.95 \cdot 10^3$	411	$2.35 \cdot 10^3$	328
20	$5.65 \cdot 10^3$	444	$8.2 \cdot 10^3$	645	$6.35 \cdot 10^3$	500
25	$9.0 \cdot 10^3$	453	$12.8 \cdot 10^3$	645	$10.0 \cdot 10^3$	503
30	$10.75 \cdot 10^3$	376	$15.0 \cdot 10^3$	524	$12.0 \cdot 10^3$	419
40	$11.25 \cdot 10^3$	221	$15.2 \cdot 10^3$	298	$12.5 \cdot 10^3$	246
45	$10.5 \cdot 10^3$	163	$14.5 \cdot 10^3$	225	$12.0 \cdot 10^3$	186
50	$9.75 \cdot 10^3$	123	$13.5 \cdot 10^3$	170	$11.2 \cdot 10^3$	141
60	$8.8 \cdot 10^3$	77	$11.5 \cdot 10^3$	100	$9.8 \cdot 10^3$	85
100	$5.2 \cdot 10^3$	16	$6.95 \cdot 10^3$	22	$5.8 \cdot 10^3$	18
125	$3.85 \cdot 10^3$	7.7	$5.2 \cdot 10^3$	10.5	$4.35 \cdot 10^3$	8.8

Formula for calculation of sensitivity

$$S = \frac{395}{Gc \cdot i} \cdot \frac{A}{T^2}$$

where:

Gc = 0,028 N/A

i = 450 μA

A = amplitude in mv

T = period in sec

Figure A4.5 LP frequency responses (tabular)

DATE 12.02.70 SITE: 01A

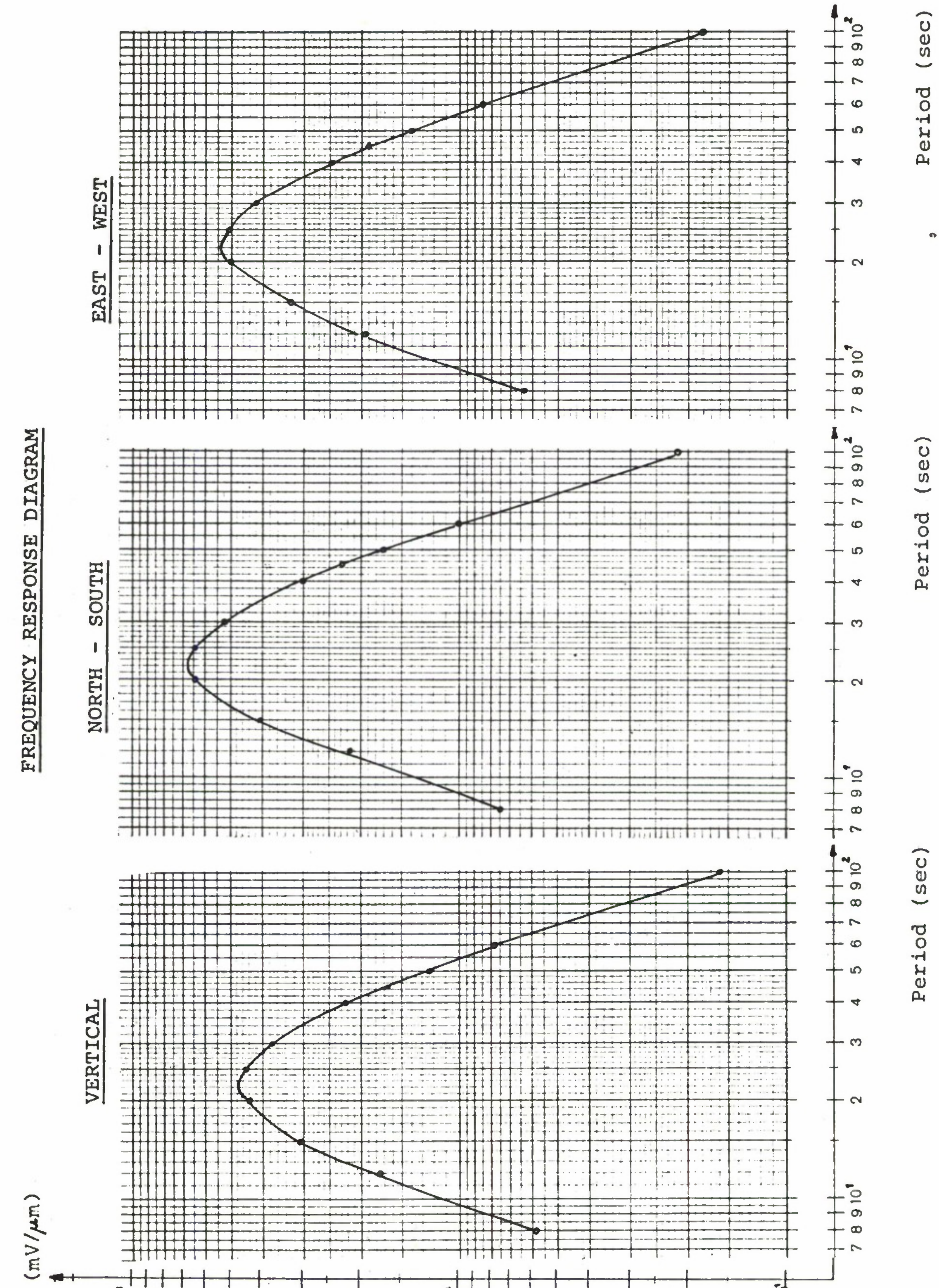


Figure A4.6 LP frequency responses

MASS POSITION ADJUSTMENTS. DATE 12.02.70 SITE 01A

Seismometer	Mass Position at to	Mass Position at t_1= to+2sec	Mass Position at t_2= t_1 -3sec
Vertical	+ 0.3 mm	+ 2.9 mm	- 1.8 mm
N - S	+ 0.4 "	+ 4.7 "	+ 0.4 "
E - W	+ 0.1 "	+ 4.2 "	+ 1.5 "

PERIOD ADJUSTMENTS.

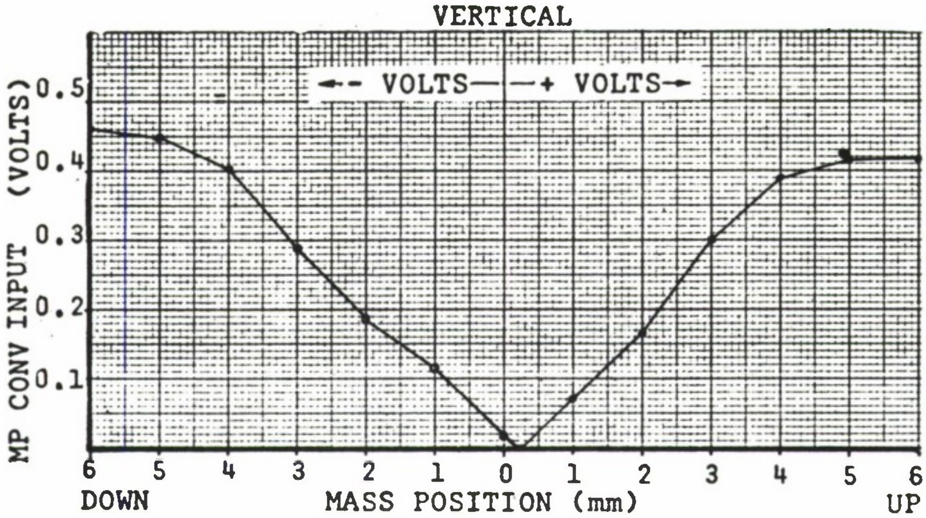
Seismometer	Free Period at to	Free period at t_1= tc + 20sec	Free period at t_2=t_1 - 30sec
Vertical	20.1 sec	20.5 sec	20.1 sec
N - S	20.3 "	20.9 "	20.1 "
E - W	20.0 "	20.5 "	20.0 "

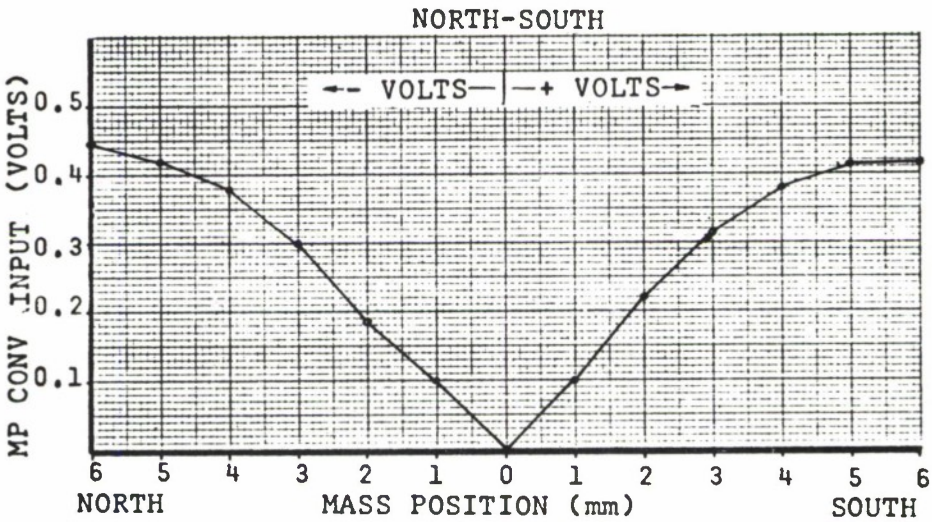
MOTOR CURRENTS.

Seismometer	MP-motor I (mA)		FP motor I (mA)	
	+	-	+	-
Vertical	168	154	70	70
N - S	70	70	70	70
E - W	70	70	70	70

Figure A4.7 LP adjustments data

MASS POSITION MONITOR CALIBRATION DIAGRAM DATE 11.02.70 SITE 01A





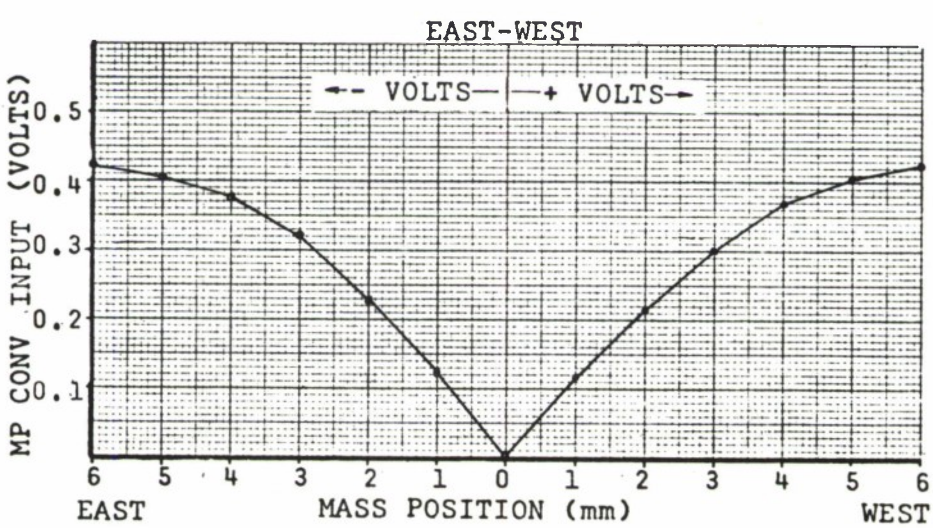


Figure A4. 8 Mass position monitor calibration data

APPENDIX 5

EMERGENCY LIGHT FOR DPC COMPUTER HALL AND THE CENTRAL TERMINAL VAULTS

A5.1 Emergency lighting system for the DPC computer hall

This system consists of:

1	charging unit, type Siemens R 102.24.12A, 24 V, max charging current 12 A
1	60 Ah/10 h Ni-Cd battery, type KAP-6
1	fuze and relay cubicle
7 ea	60 W/24 V lamps w/accessories, installed in a choice of the ordinary light fixtures in the ceiling of the computer hall (see Figure 8.5)

The system senses the presence of the mains voltage, and turns on the emergency light in cases of mains failure. When the mains voltage returns, the batteries are automatically recharged and kept fully charged.

A5.2 Emergency lights for the CTVs

An automatically recharging torch lamp with Ni-Cd battery is installed inside and near the entrance of each CTV. Since the CTVs are not manned, mains failure does not turn on the emergency light. However, a small charging unit sees that the battery is always fully charged.

The lamp w/charger, shown in Figure A5.1, has the following specifications:

Battery	Ni-Cd, type NIFE D-22, 22 Ah/5 h
Bulb, two filaments	Full light 2.4 V/15 W Half light 2.4 V/5 W
Charger	Fully automatic, charging current 2.2 A
Max burning time	Full light 3.5 hours Half light 11 "

Figure A5.1 Emergency lamp unit for CTV use

APPENDIX 6

IBM DOCUMENTATION OF NORSAR DPC EQUIPMENT AND PROGRAMS

Technical documentation of the NORSAR DPC equipment and programs furnished by IBM is contained in the set of documents listed and described below. This set forms part of the full documentation for the Integrated Seismic Research Signal Processing System (ISRSPS) which also covers the LASA and SAAC facilities. Each document is assigned an IBM REF number that will identify it in all cross-referencing within this set of documents. The suffix N to some of the REF numbers indicates that the document is specific to the NORSAR system and that there also exist LASA and SAAC equivalents.

A6.1 REF numbers with document titles

101	ISRSPS General System Specification
102	ISRSPS General Equipment Specification
103	ISRSPS Interface Equipment Design Specification
104N	ISRSPS Interface Equipment Processing Specification
105	ISRSPS Interface Equipment Test Specification
106	ISRSPS Interface Equipment Operations and Maintenance Manual
107N	ISRSPS Experimental Operations Console Specification
108N	ISRSPS Experimental Operations Console Test Specification
109N	ISRSPS Experimental Operations Console Operations and Maintenance Manual
110N	ISRSPS Program Specification
111N	ISRSPS Program Manual
112	ISRSPS System Test Specification
113N	ISRSPS System Operating Manual

A6.2 Description of document contents

REF 101 establishes performance and design requirements for both equipment and programs in the ISRSPS. These requirements are expressed in functional terms.

REF 102 identifies all items of ISRSPS equipment and specifies equipment interfaces with already existing or GFE items. Standard IBM commercial equipment items are identified by model and feature numbers. Performance and design requirements are established for all other items of ISRSPS equipment except the Interface Equipment (SPS, REF 103), and the Experimental Operations Console (EOC, REF 107N). Diagrams are included of all equipment configurations, including test configurations.

REF 103 establishes the detailed performance and design requirements for the design, development, test and qualification of the Interface Equipment (SPS) excluding microcoded functions.

REF 104N establishes the detailed performance and design requirements for the SPS microprograms. The organization and design of the programs are described. Implementation details are provided in the form of CAS sheets in a separately bound appendix.

REF 105 establishes detailed qualification requirements, criteria, methods and responsibilities for testing the SPS, excluding microcoded functions.

REF 106 contains information for the use, guidance and training of personnel operating and maintaining the SPS. The manual contains a detailed technical description of the equipment with timing and logic diagrams.

REF 107N establishes detailed performance and design requirements for the design, development, test and qualification of the NORSAR Experimental Operations Console.

REF 108N establishes detailed qualification requirements, criteria, methods and responsibilities for testing the Experimental Operations Console.

REF 109N contains information for the use, guidance and training of personnel maintaining the Experimental Operations Console.

REF 110N establishes the performance and design requirements for the ISRSPS System/360 programs. This document translates the functionally expressed specifications of REF 101 into technically expressed distinct computer program tasks. The organization of the programs is described and also the overall data flow in the system. All program interfaces are fully detailed. Detailed flowcharts are not required.

REF 111N contains detailed technical descriptions of the ISRSPS System/360 programs, including program functions, structures, operating environment, data organization and implementation. Flowcharts and narrative descriptions are included, and source language listings are provided in a separately bound appendix.

REF 112 establishes the tests to be performed for ISRSPS to verify that equipment and programs function together to fulfill the requirements of REF 101.

REF 113N contains information for the use and guidance of the personnel operating ISRSPS. It contains a summarized functional analysis, comprehensive operator instructions, and a physical description of the equipment and its interconnections.

APPENDIX 7

SOME ACRONYMS USED IN THE REPORT

AFSC	Air Force Systems Command
ARPA	Advanced Research Projects Agency
CTV	Central Terminal Vault
DPC	Data Processing Center
ESD	Electronic Systems Division (of AFSC, USAF)
GFE	(US) Government Furnished Equipment
IFA	Institute for Atomic Energy
KCIN	Kjeller Computer Installation
LASA	Large Seismic Array (the Montana array)
LFK	Luftforsvarets forsyningskommando (Norwegian Air Force Supply Command)
LPV	Long Period Vault
MC	Maintenance Center
NDRE	Norwegian Defence Research Establishment
NORSAR	Norwegian Seismic Array
NTA	Norwegian Telecommunications (formerly Telegraph) Administration
NTNF	Norges Teknisk-Naturvitenskapelige Forskningsråd (The Royal Norwegian Council for Scientific and Industrial Research)
SAAC	Seismic Array Analysis Center
SLEM	Short and Long (Period) Electronic Module
SP	Short Period (Seismometer)
WHV	Well Head Vault (Superstructure on top of SP seismometer hole)

UNCLASSIFIED

Security Classification

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13 ABSTRACT

Project NORSAR concerns installation and operation of a large seismic array in S-E Norway.

This report covers the field installations of the so-called C-ring subarrays, i e 13 of the 14 peripheral subarrays, and also the establishing of a data processing center (DPC) and a maintenance center at Kjeller and telecommunication links between the DPC and the individual subarrays.

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KEY WORDS:

NORSAR - Norwegian Seismic Array

Norway - Large Aperture Seismic Array

Large Aperture Seismic Array

Seismic Array